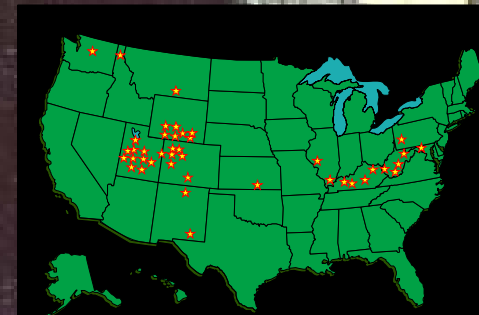


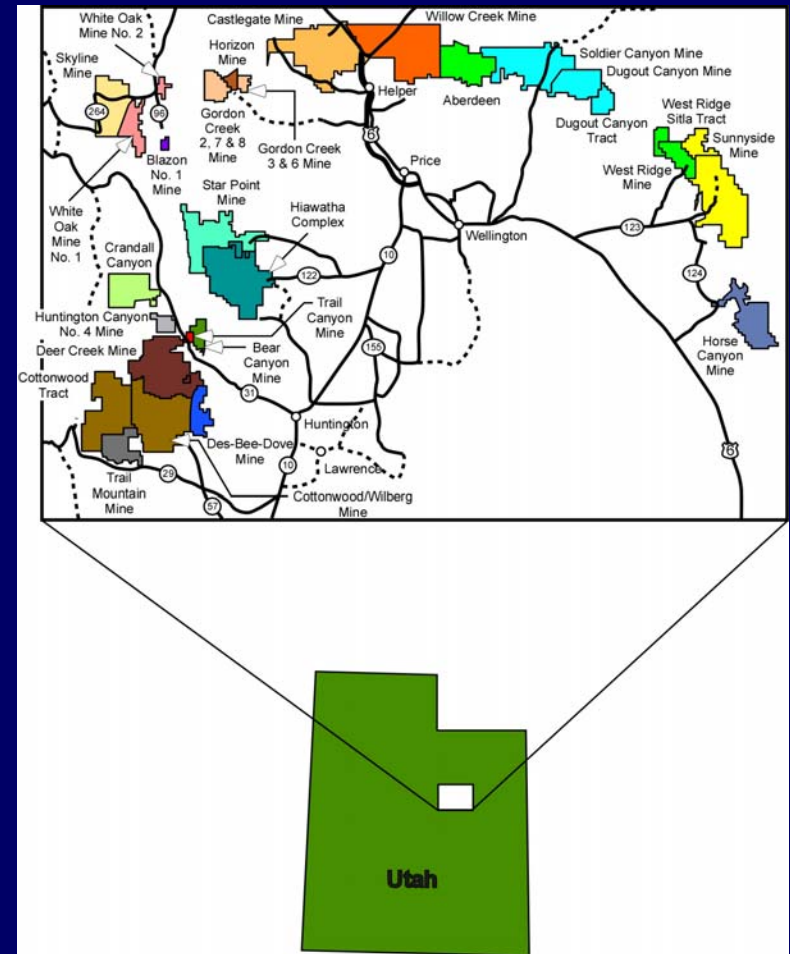
Overview of 2- and 3-Entry Yielding Gate Pillar Systems in Utah Mines

Maleki Technologies, Inc.
Spokane, WA



Presentation Outline

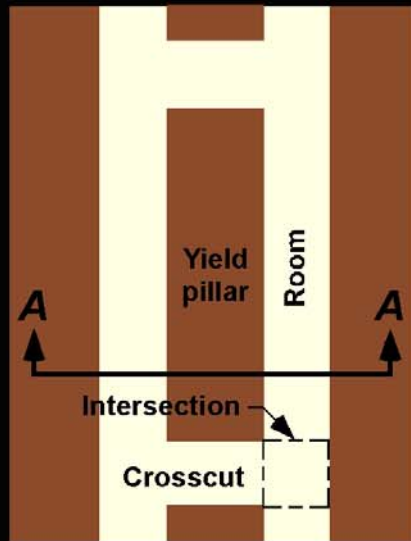
- Introduction
- Overview of geologic setting of Utah mines
- Historic review of gate road studies in three Utah mines
- Mill Fork geotechnical program
- Data analyses and model calibration
- Comparative evaluation of 2- and 3- entry system
- Conclusions
- Preliminary design methodology



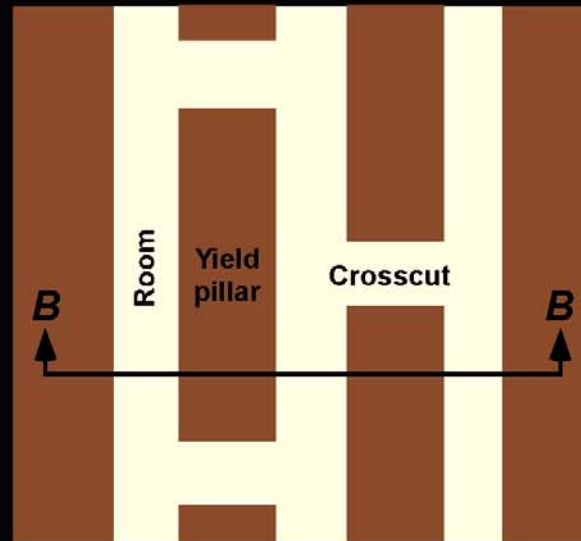
Historic Justifications

- Weak ground exposure
- Rib and pillar outburst
- Pressure arch and load transfer
- Total system response during the entire mining cycle under variable, burst-prone geologic and stress conditions
- Depth of cover important but not the only decisive factor
- Yielding gate pillars instead of critical-abutment pillars in multiple seam operations

Two-entry

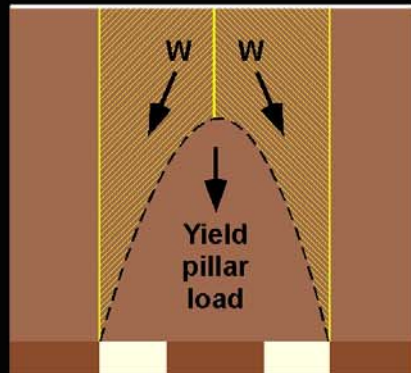


Three-entry



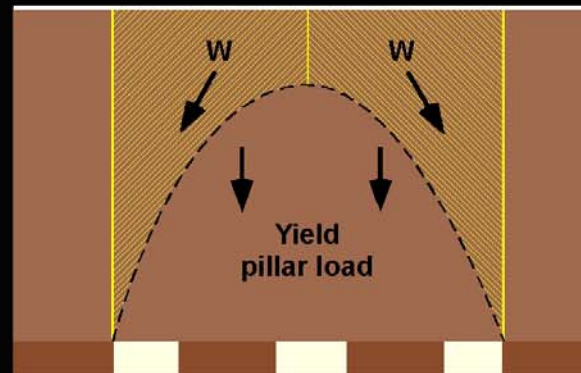
Plan view

Surface



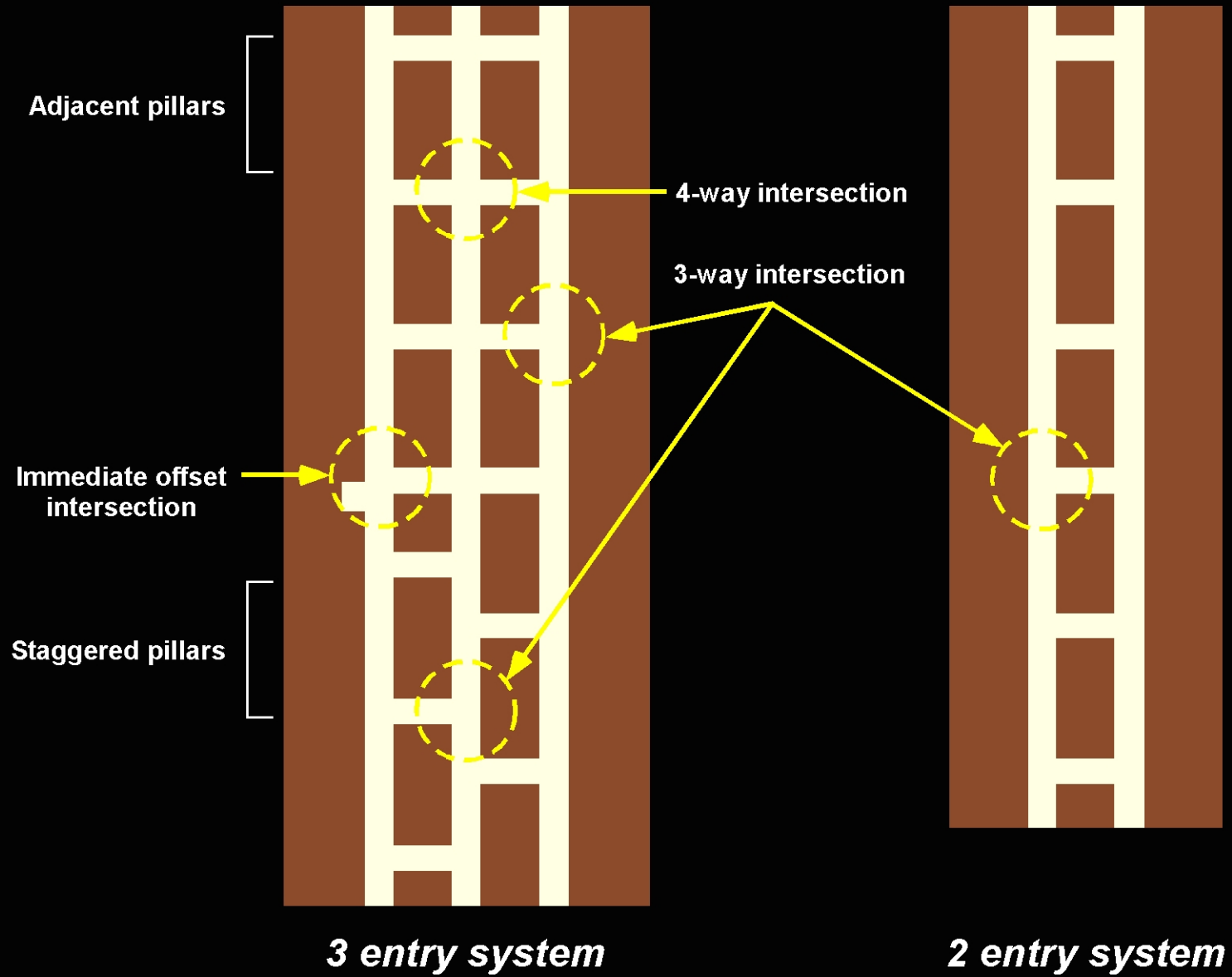
Abutment | Development width | Abutment

Surface



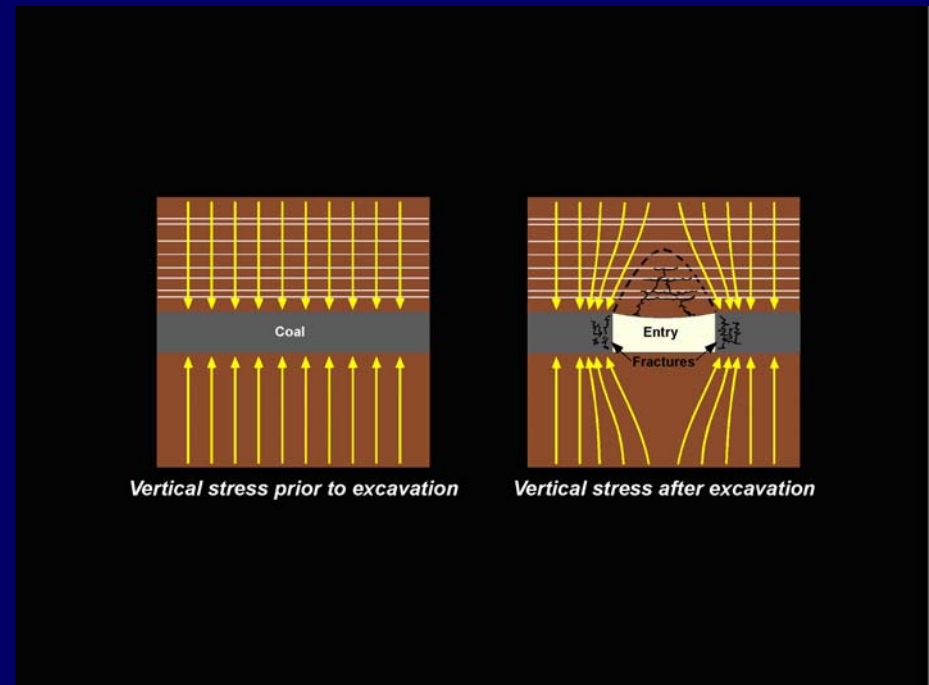
Abutment | Development width | Abutment

Cross section

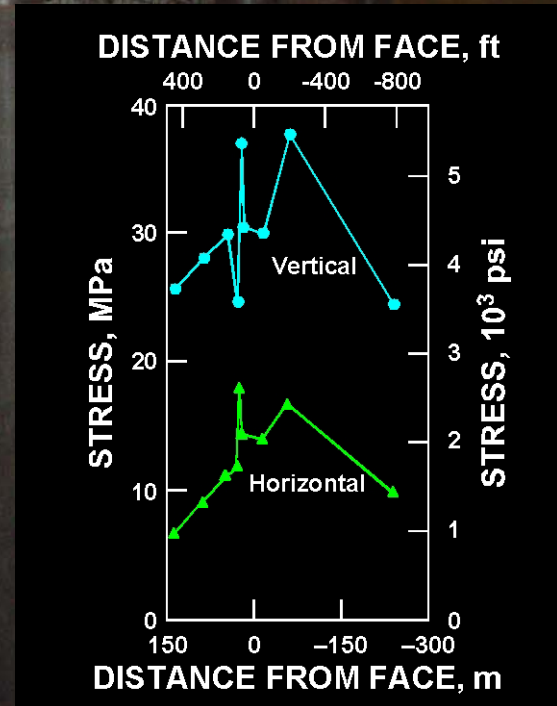


Ground Exposure Increase Two-Three-entry

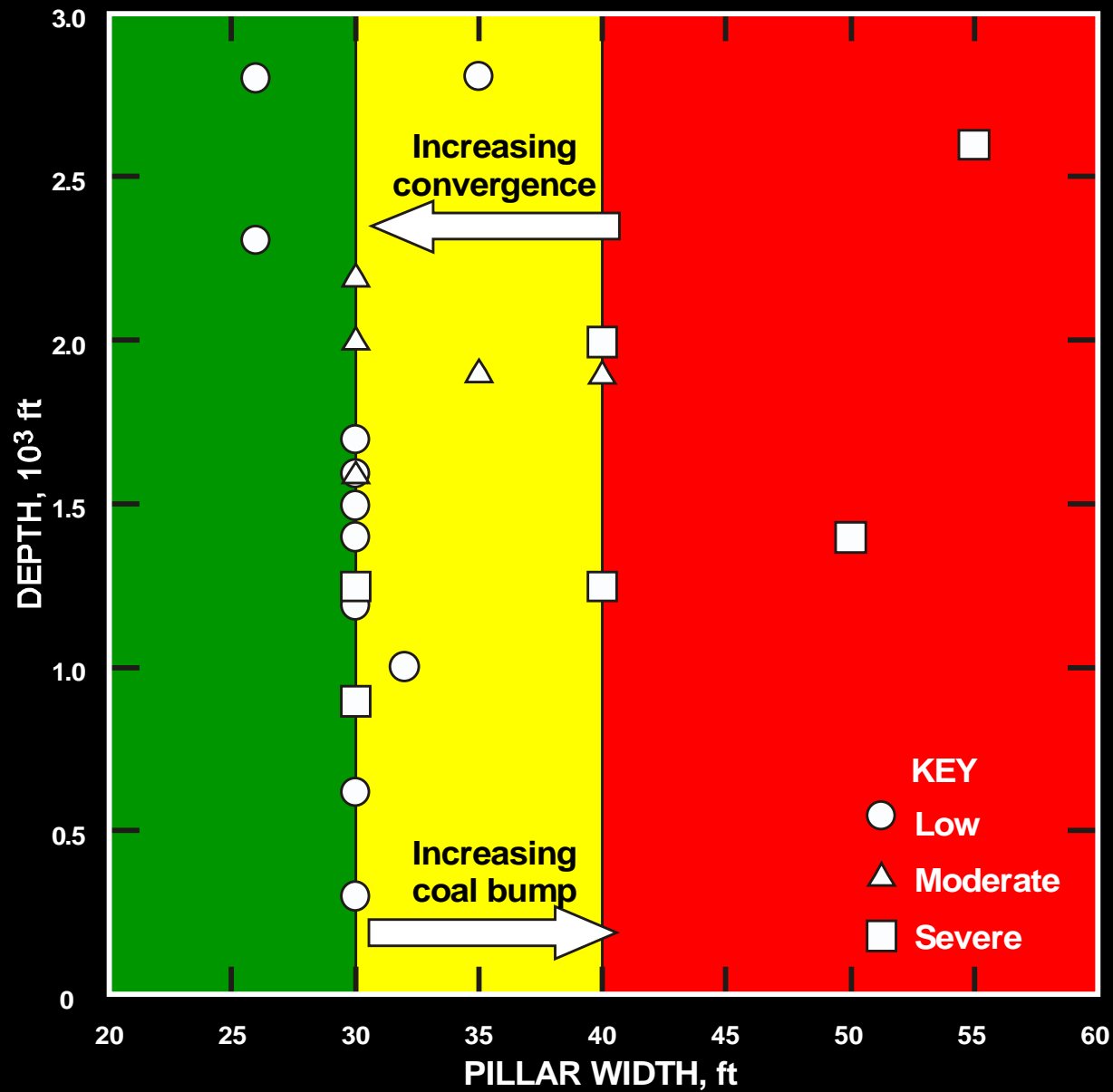
- Total development width 66'-114' or 73%
- Roof area exposed per crosscut advance 4860-7560 sq-ft or 56%
- Total rib exposure per crosscut advance 500'-760' or 52%
- Number of intersections per crosscut advance from 4-6 or 52%
- Niosh data suggests roof failure is eight-times more likely at intersections than rooms.

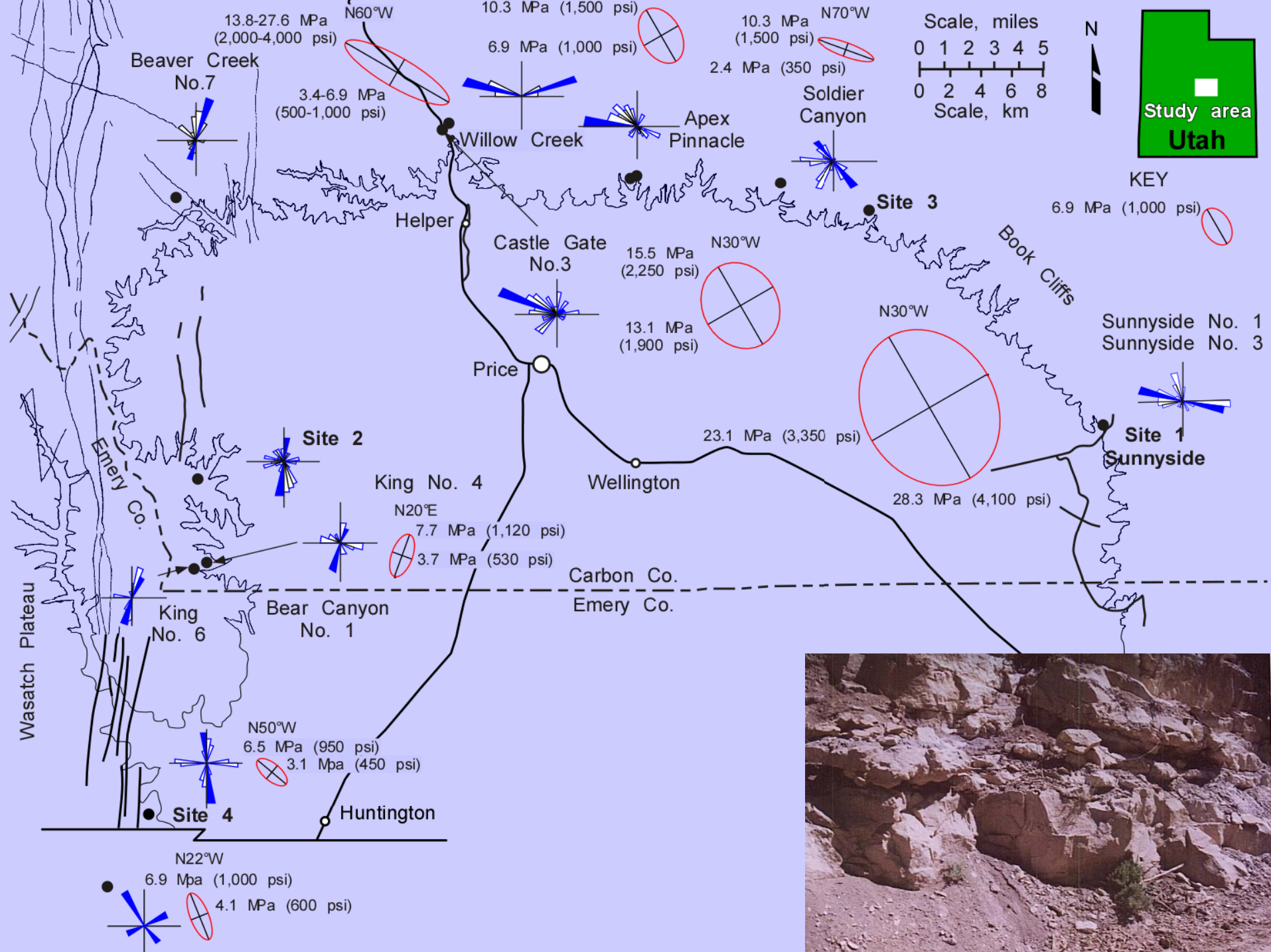






Wasatch Plateau and Bookcliff





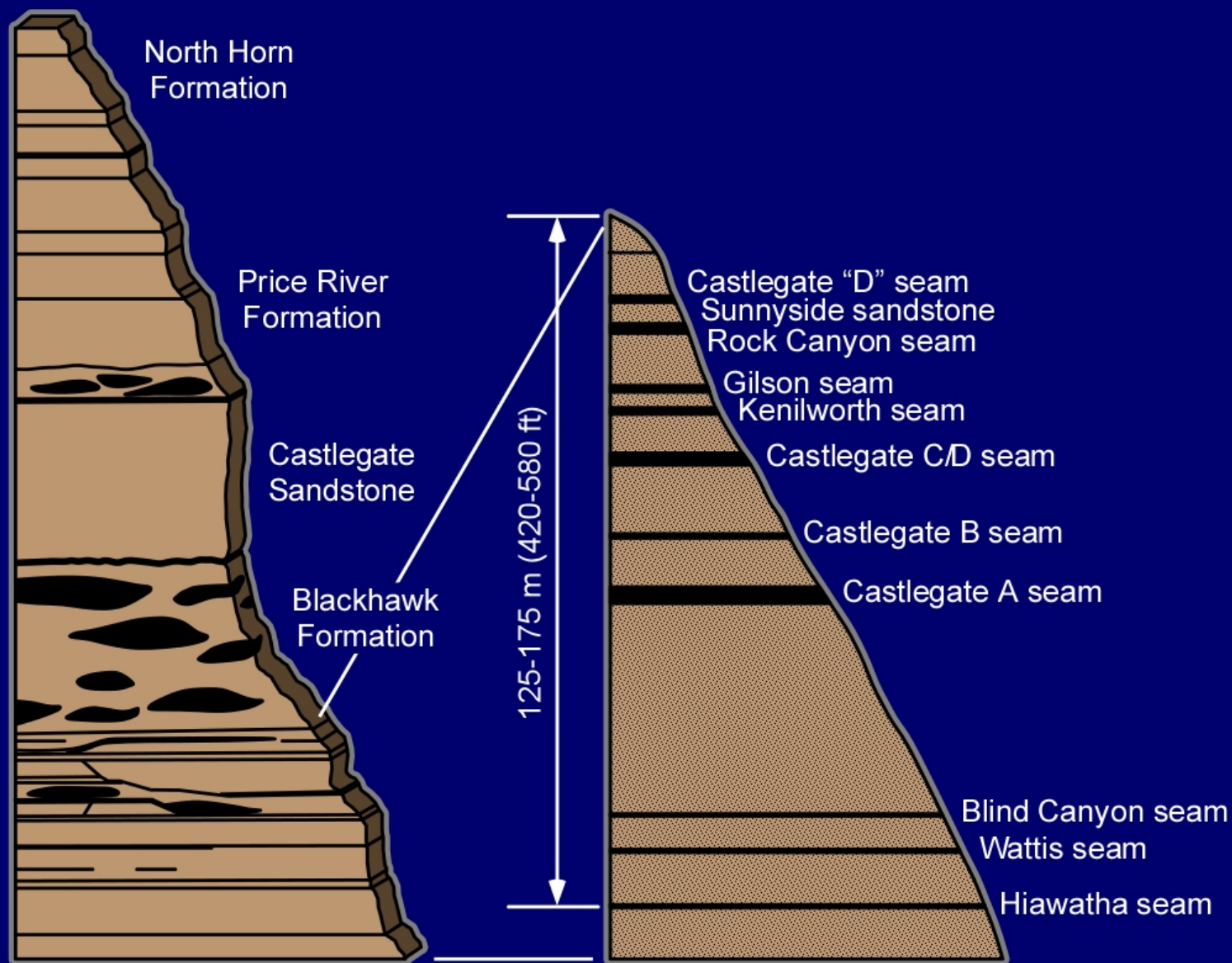


Table 1. Comparisons of unconfined compressive strength (UCS) and Young's modulus (E) for selected lithologies (psi)

	Site 1-Sunnyside		Site 2-PMC		Site 3- CFC		Site 4-Energy West	
	UCS	E	UCS	E	UCS	E	UCS	E
Roof	12000 19000	.55e6 3.24e6	3000 14000	1.8e6	7000 22900	4e6	7000 20000	5.5e6
Seam	3500	.33e6	2500	.3e6	5000	.5e6	3000	.6e6
Floor	12000 19000	.55e6 3.24e6	12000	2.7e6	9000 23000	1.4e6	10000	3.5e6





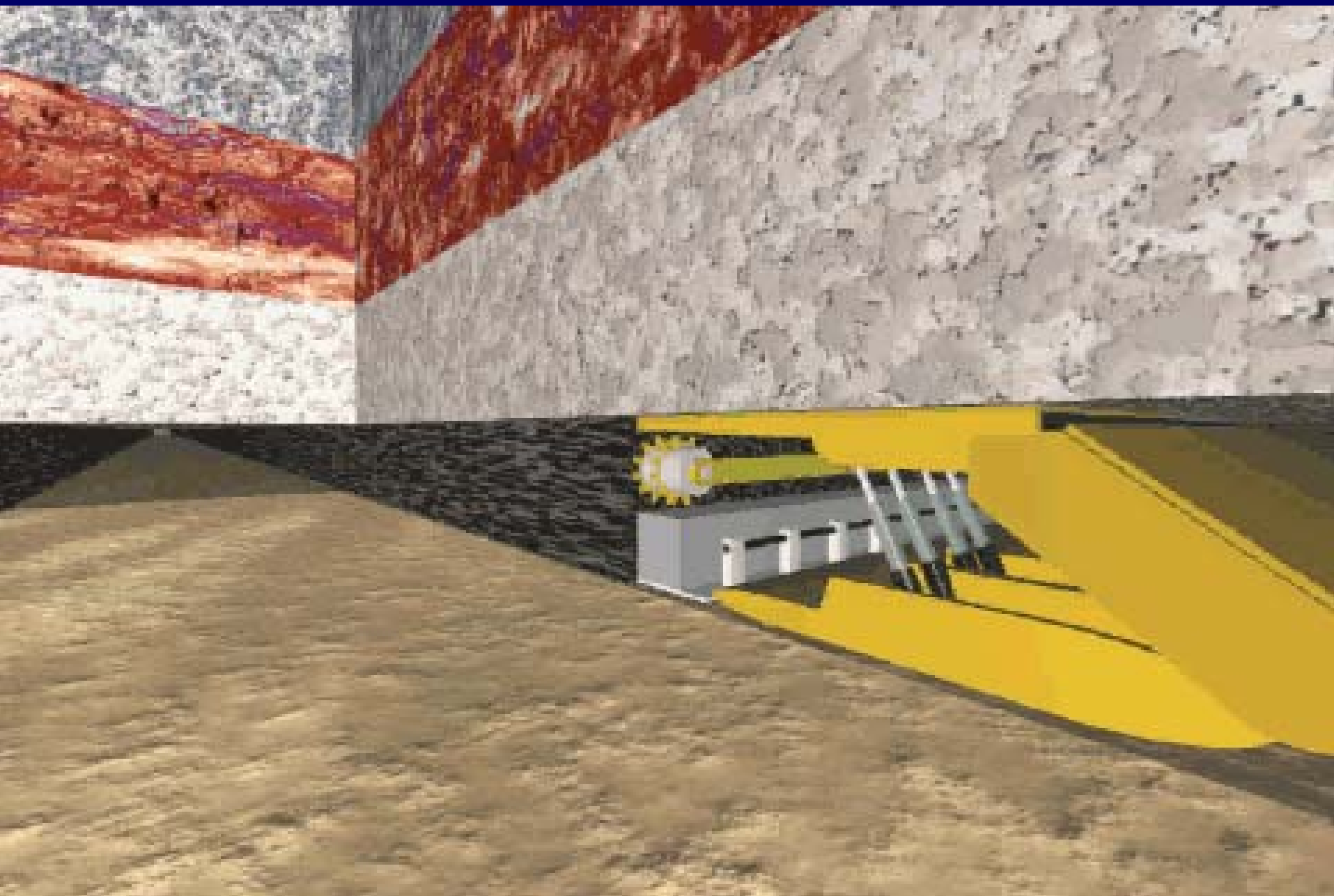
CALIBRATION/VERIFICATION
Date: 1/17/05 By: SW
Due: 1/17/06
Lab/Serial: #271
Bulinger & Associates, Inc.

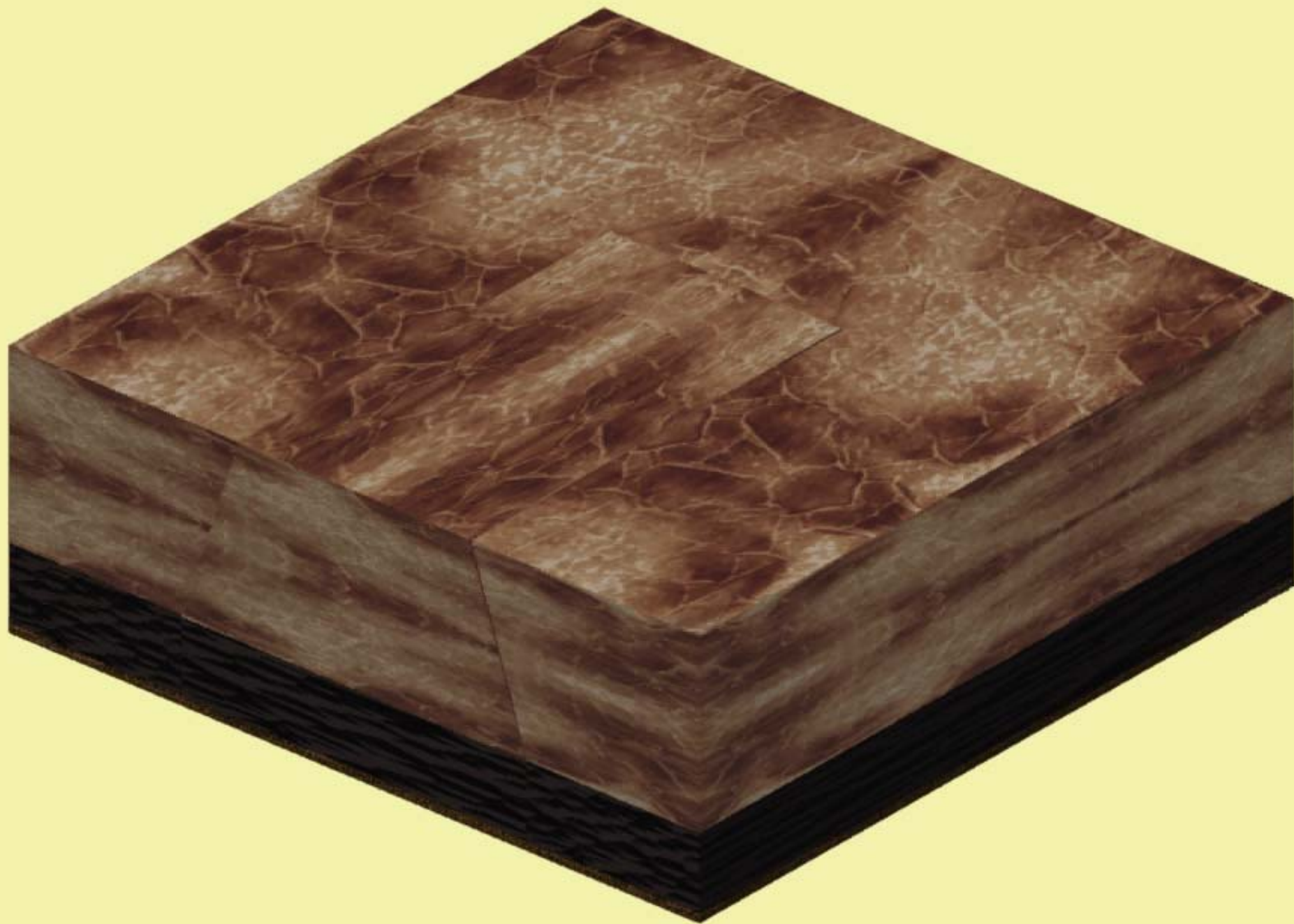


D'SESI
L-111
L-111

Emerging Trends in Utah Mines

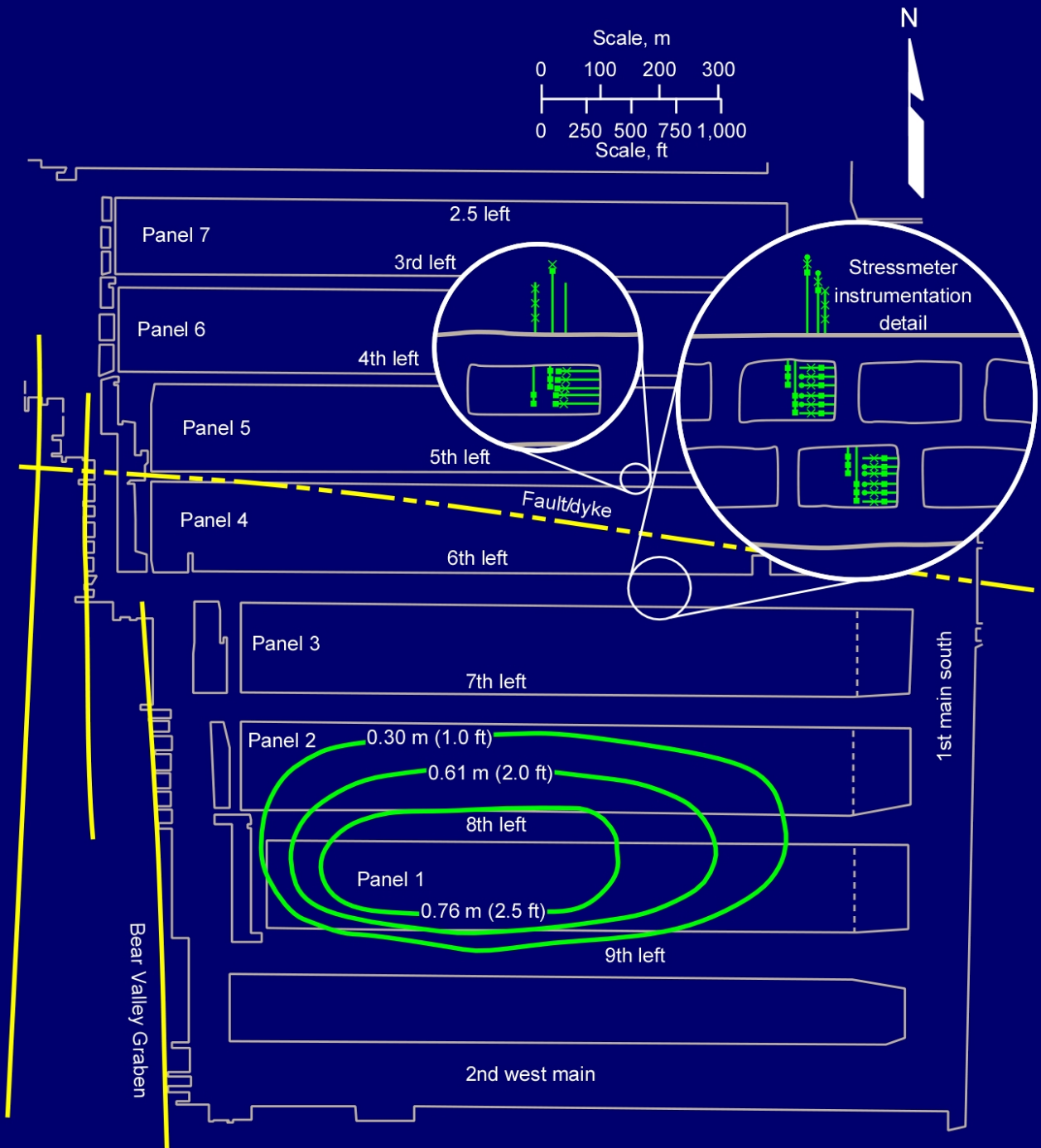
- Limited longwall reserves
- High stress environment
- Variable topographies
- Fluvial deposits with large variability over short distances near the margin of basins
- Multiple-seam mining interactions
- Competent overburden strata, lagging cave, long load-transfer distances and seismicity
- Industry constantly studying alternative methods and layouts including use of barriers





Review of USBM/MTI Investigations

- Geotechnical measurements in WP and Book Cliffs (sites 2 and 3)
- Comprehensive studies and interviews, Sunnyside mines (site 1)
- Single-entry investigations, Sunnyside mines



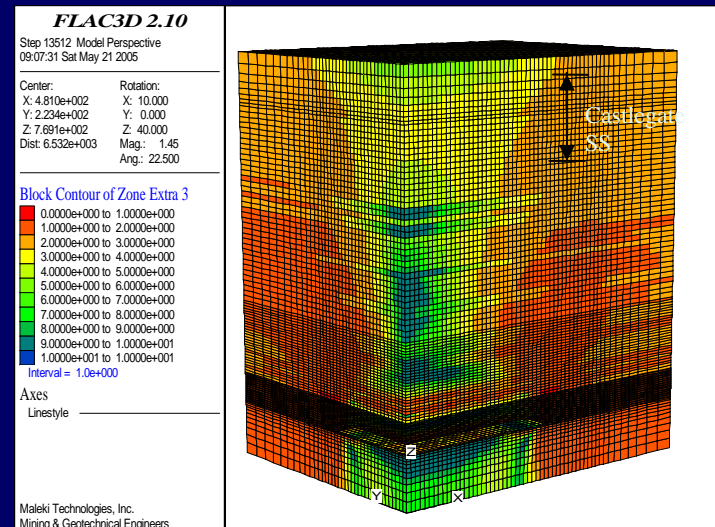
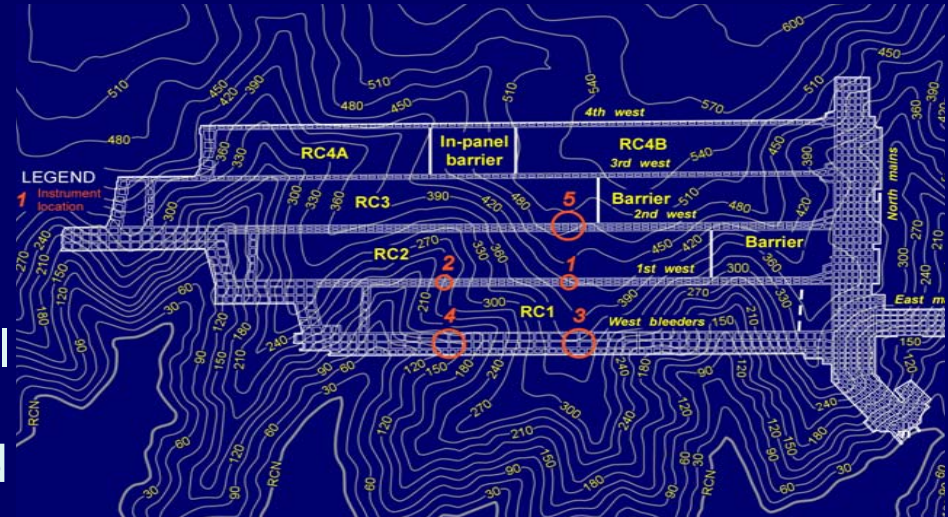
USBM-Cyprus PMC Conclusions

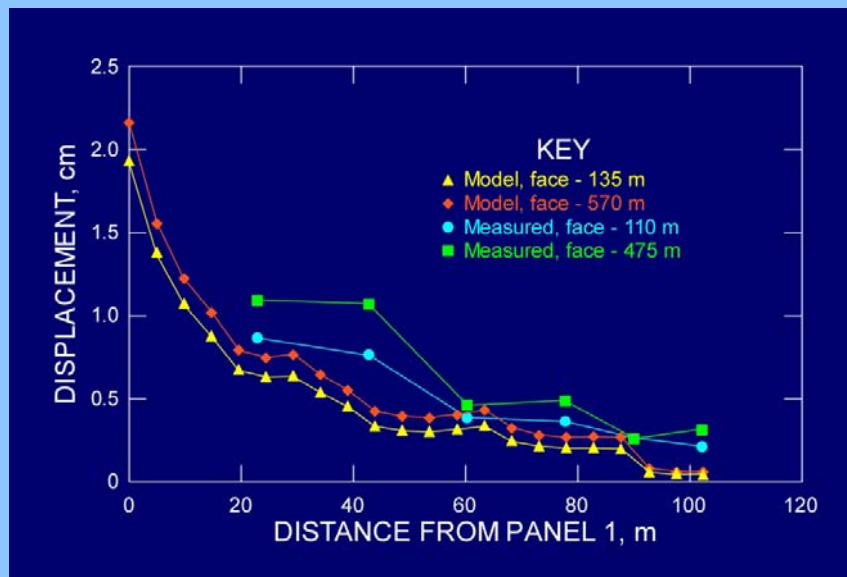
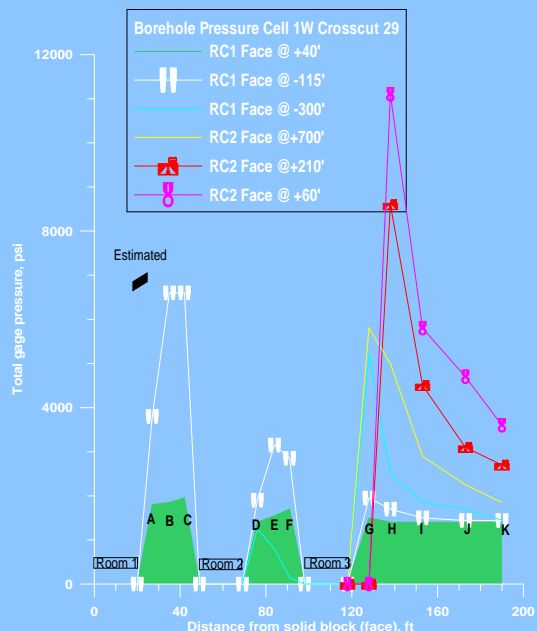
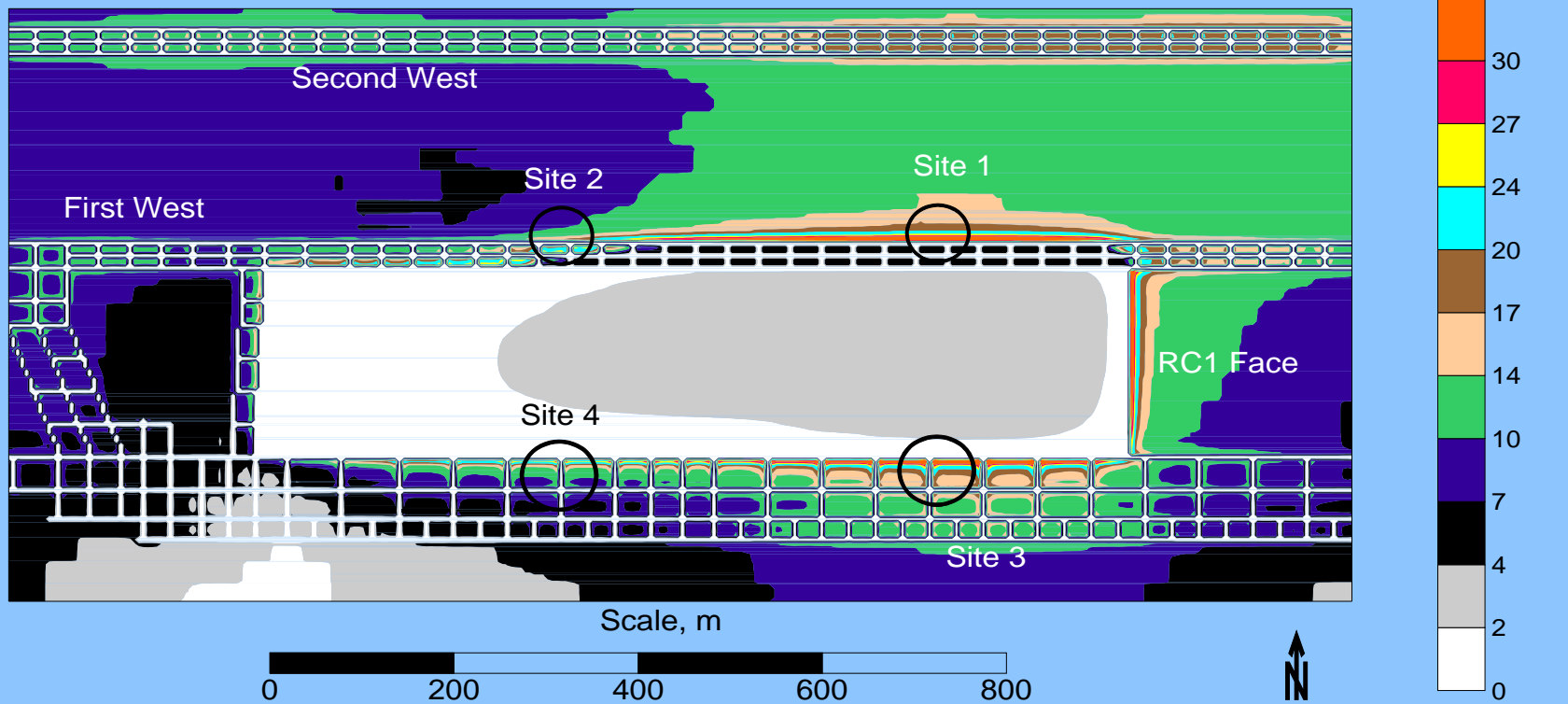
3-entry 50' pillars to 2-entry 30' pillars

- Marked improvement in gateroad stability with minor floor heave and reduced rib sloughage
- A reduction in roof falls, on development and retreat
- A reduction in gate support requirement particularly at the tailgate
- Reduction on load transfer toward underlying lower seam workings, resulting in improved ground conditions in mining this seam

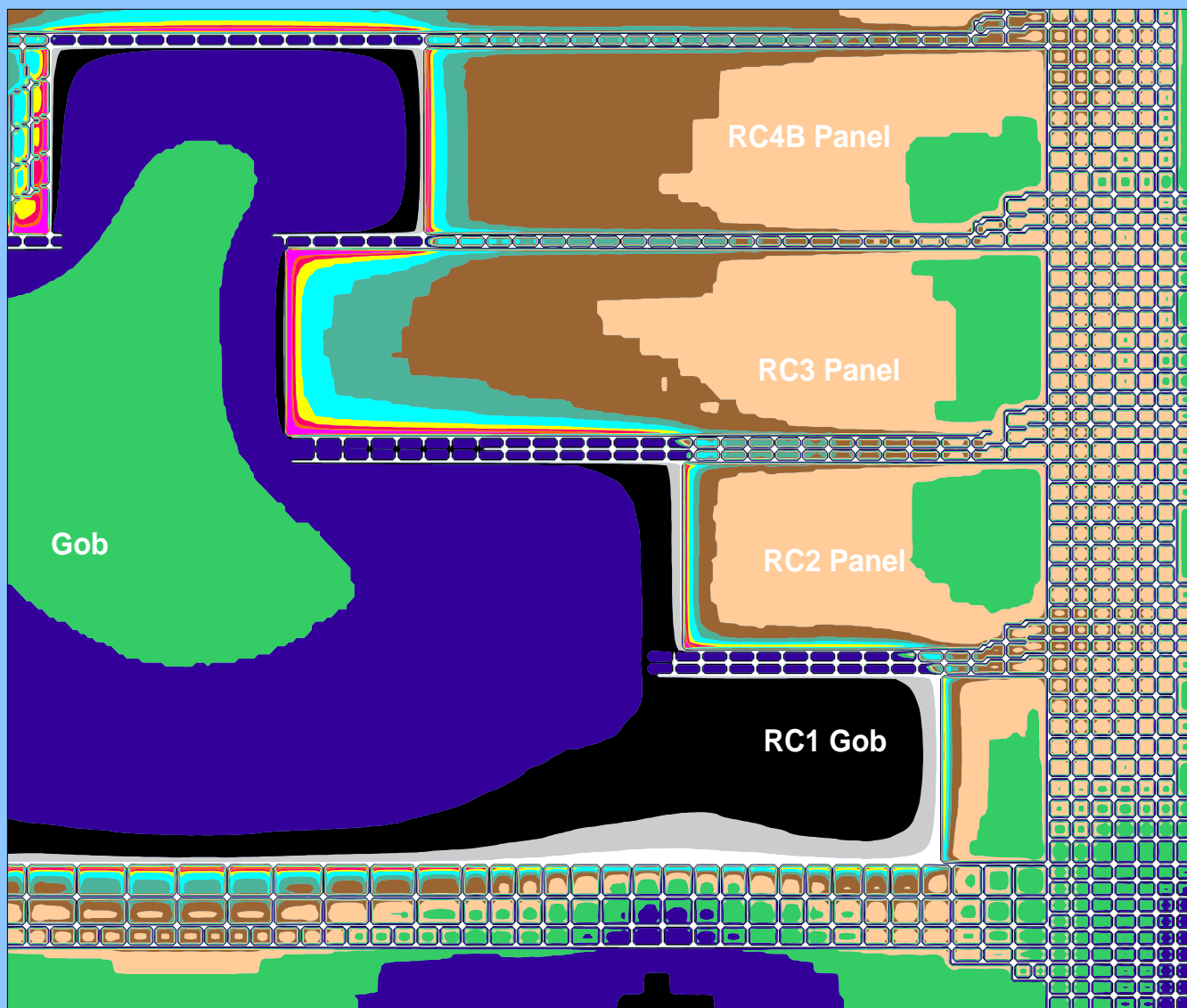
MTI-CFC Investigations

- Premining investigations in Soldier Canyon/Dugout
- Laboratory and field investigations
- Numerical modeling and model calibrations
- Underground observations and verifications
- Innovative 3D modeling to estimate seismicity for different orientations and panel-barrier designs
- Series of publications and presentations

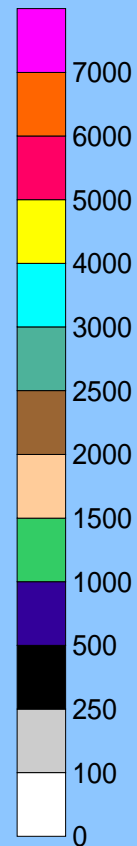




RC4B, 1600-ft retreat

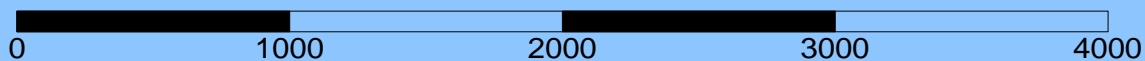


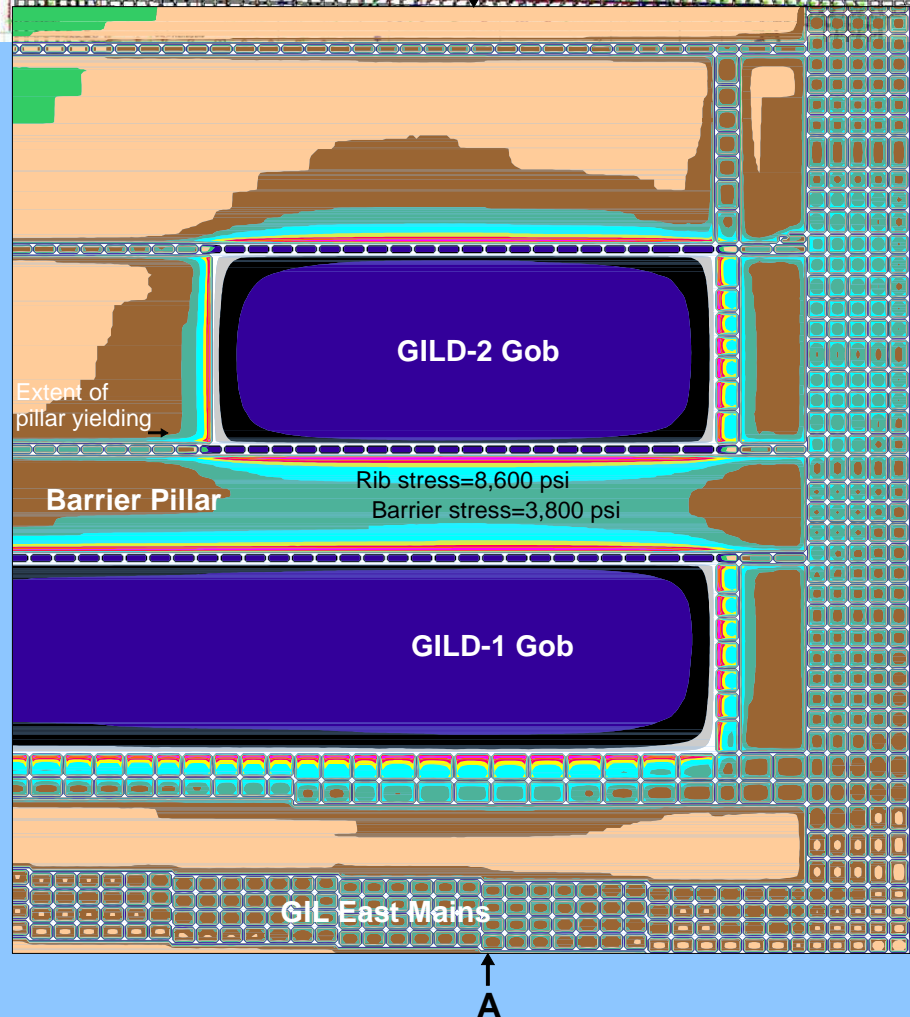
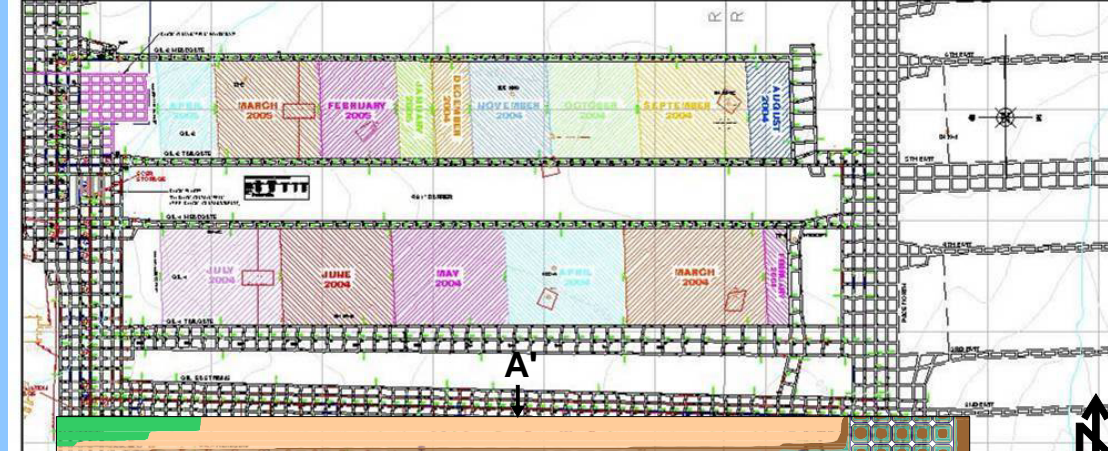
Stress, psi



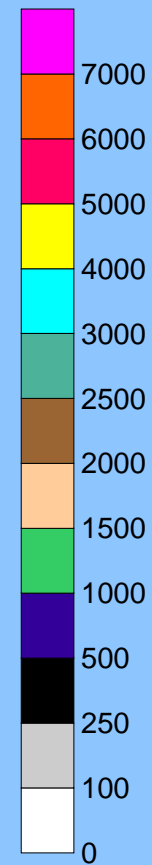
Dip 7 Deg.

Scale, ft





Stress, psi

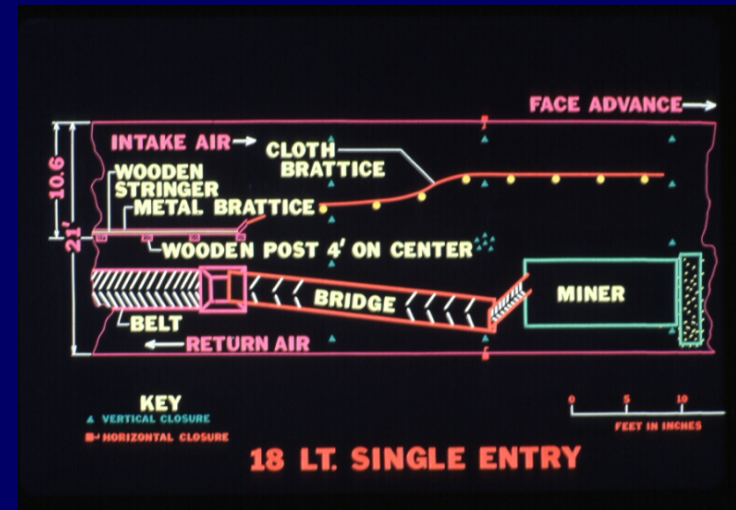


USBM Sunnyside Interview Conclusions

- 30-year longwall history, 30 long-term employees, 1000-pages of field notes
- Cantilevering roof near the face results in severe instabilities such as bumps and roof falls; severity of bumps proportional to cantilever length
- Large coal pillars can be safely mined under deep cover, however, substantial evidence suggests that large, stiff pillars become highly bump-prone when subjected to abutment loads
- When a yielding gate pillar is used, limiting the overall width of gateroad is considered very important for roof stability
- Present 2-entry yield pillar system has virtually eliminated severe tailgate pillar bumps and contributed to reducing face bumps near the tailgate corner
- Almost without exception, miners expressed comfort in working in the current two-entry system developed over 30-year

USBM Single-Entry Evaluation

- Partition a single-entry using different cribbing material
- Evaluate at the Sunnyside mine
- USBM considered it a success for ground control but more expensive



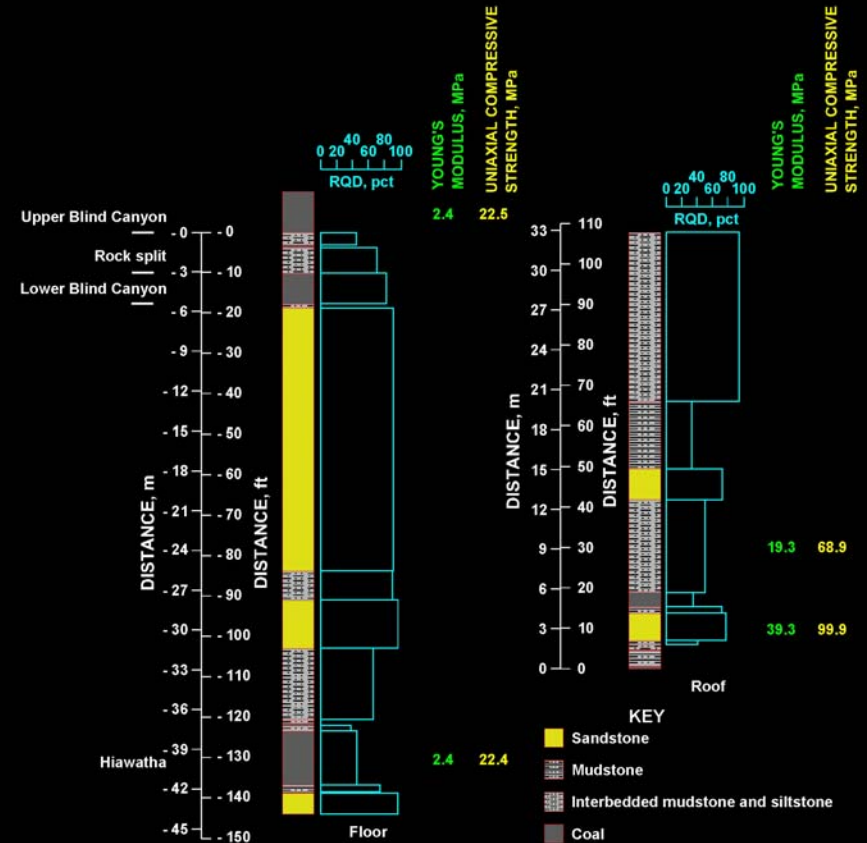
WV Single-Entry Evaluation

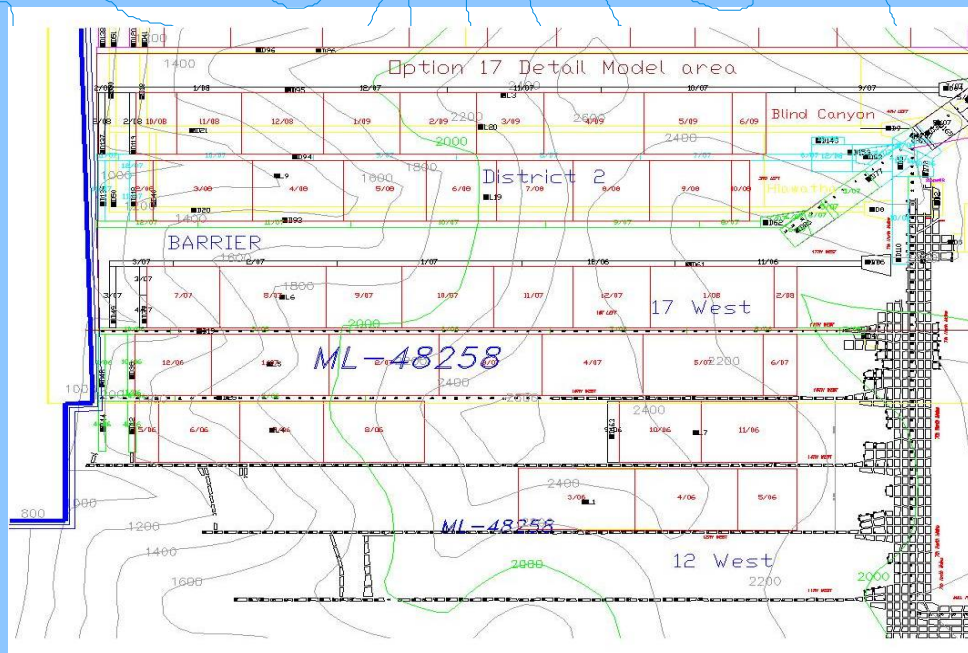
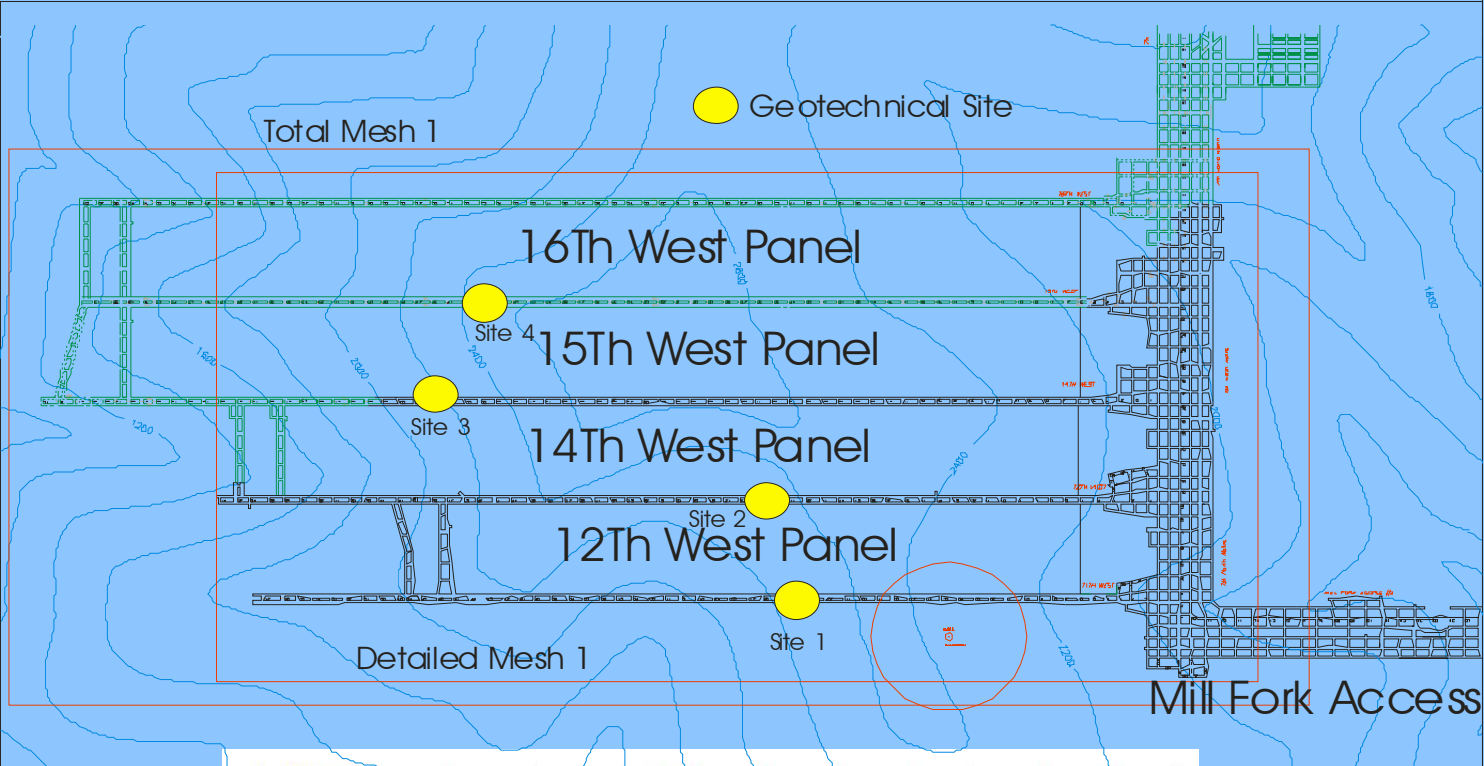
- Utilize Tunnel-boring machine for rapid development
- Satisfy existing ventilation requirements



EW-Mill Fork Investigations

- Geologic investigations during development mining and exploratory drilling
- Laboratory and field investigations since 1985
- Numerical modeling and model calibrations
- Underground observations and verifications
- Innovative designs to determine critical stress levels and limits to longwall mining



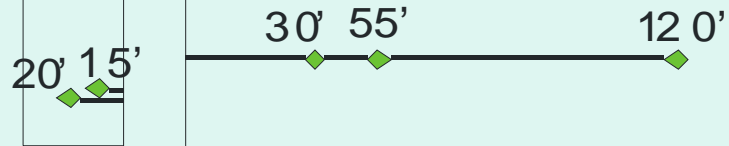


Instrument Location 1, 11 W

PLAN

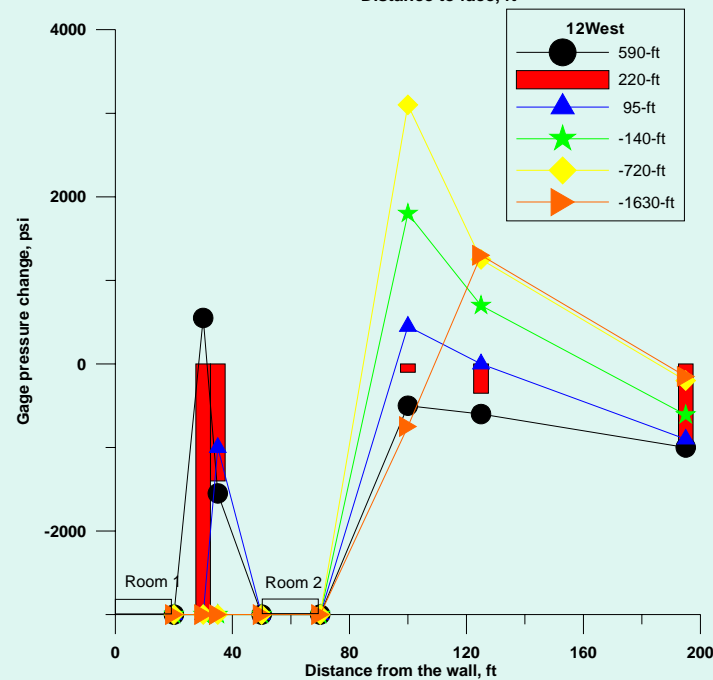
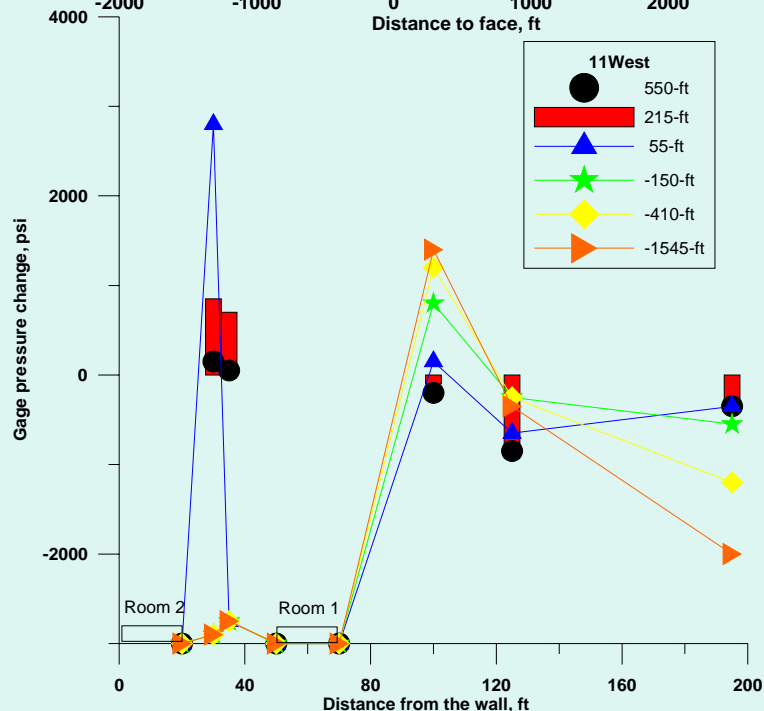
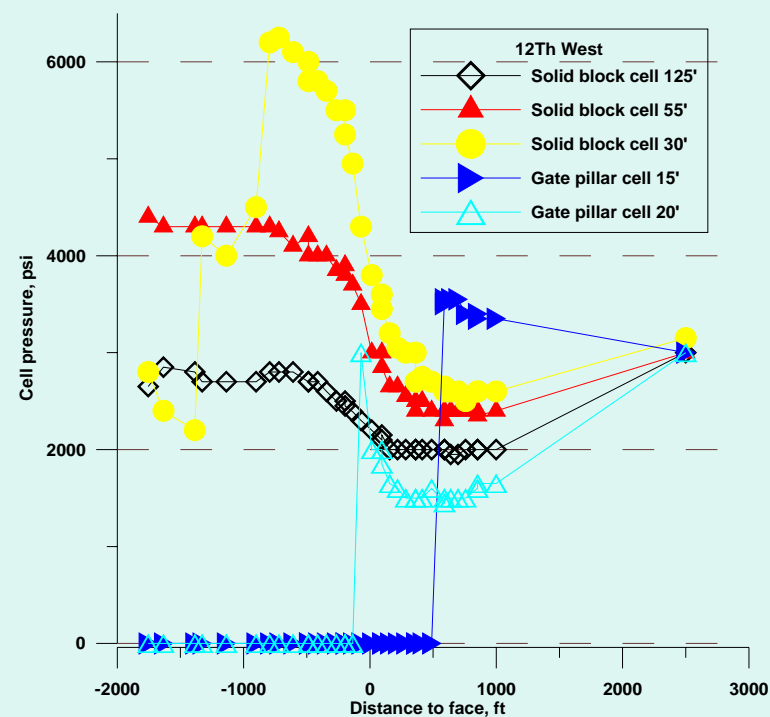
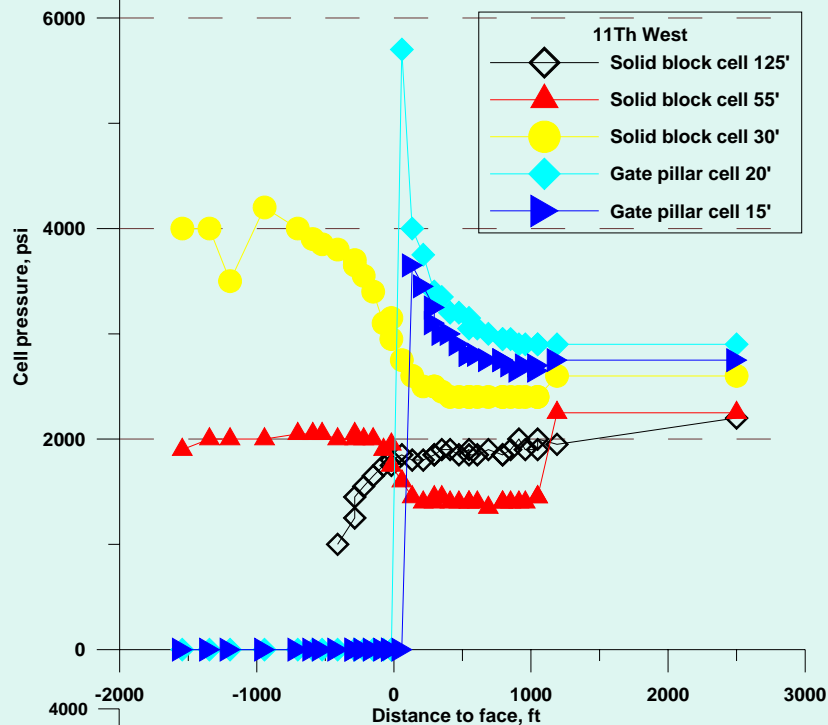
Panel

Side Block



↑ Borehole pressure cell





Load Transfer Distance and Pillar Behavior

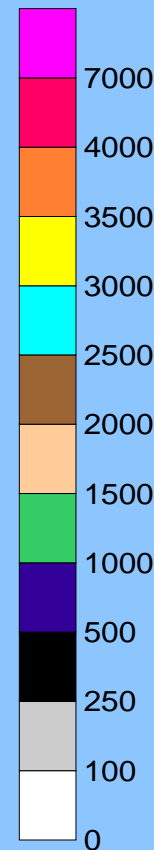
- Long load transfer distances exceeding 850-1000-ft
- 11W pillars take the load and then unload as the face approach the instruments transferring loads to the sides (30-ft cell)
- 12W pillar near peak stress unloading slightly @ 590' face position
- Pillar peak/residual strength 3850/700 psi

Calibration

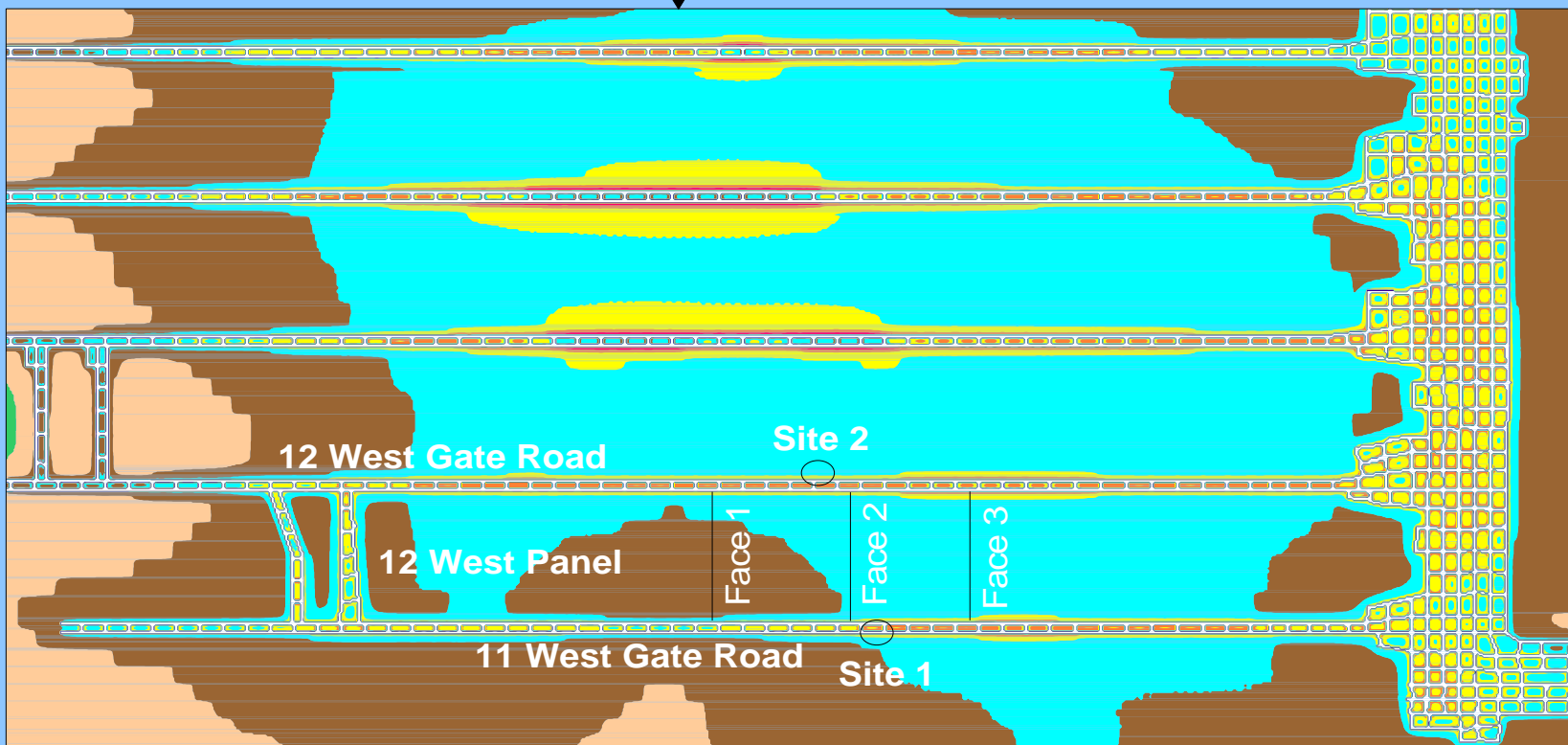
- Development and three retreat positions in the 12W panel
- Face 1, face at 590-ft from 12W site
- Face 2, face at 55-ft from 11W site
- Face 3, face at -720-ft from the 12W site
- 16 parametric analyses altering elastic properties, peak pillar strength, and cave conditions
- Use additional data during the retreat of 14W to test the model



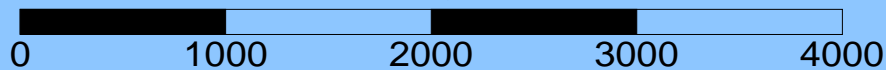
Stress, psi



A

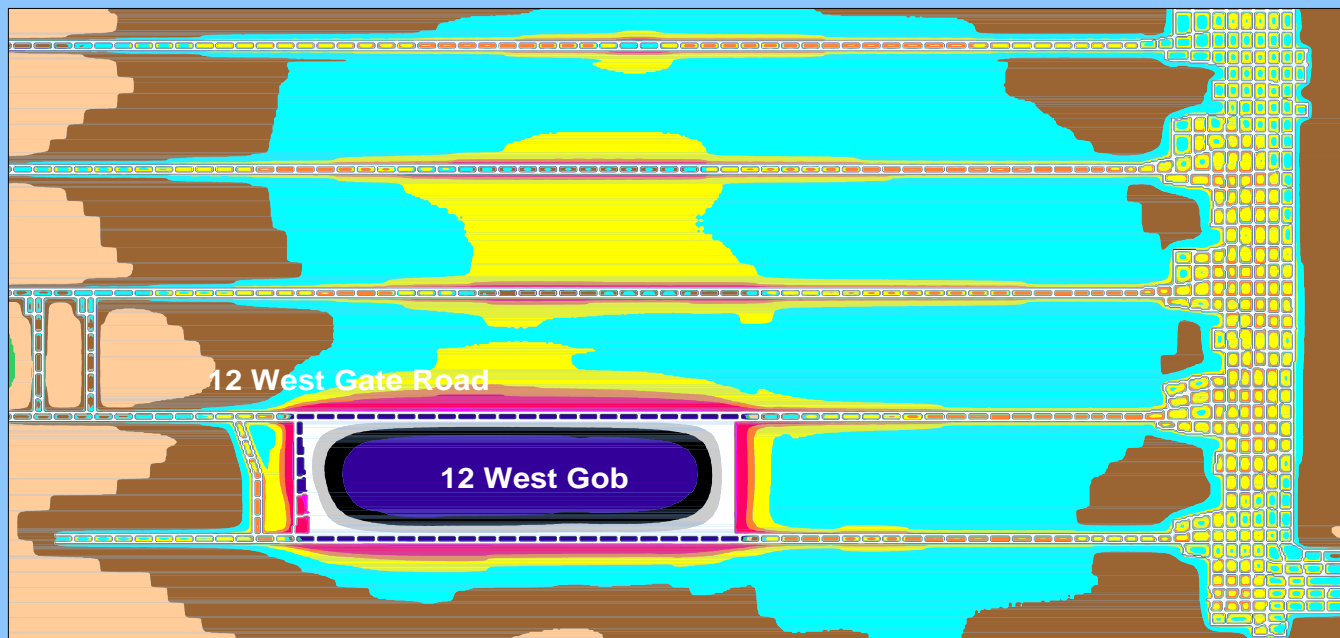


Scale, ft

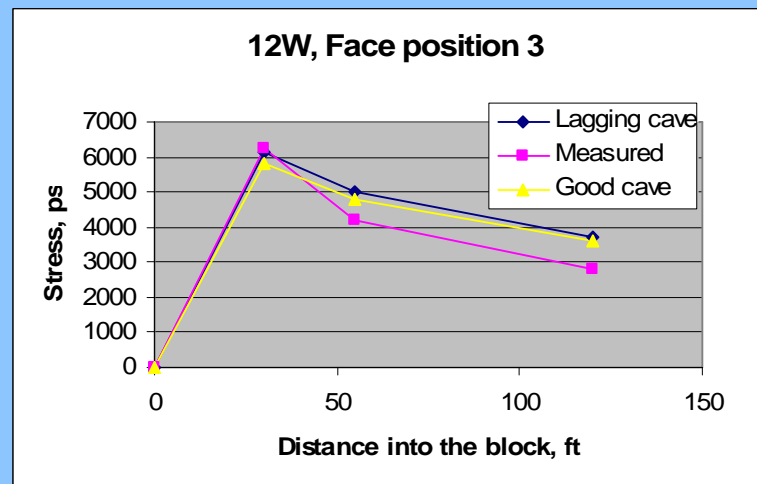
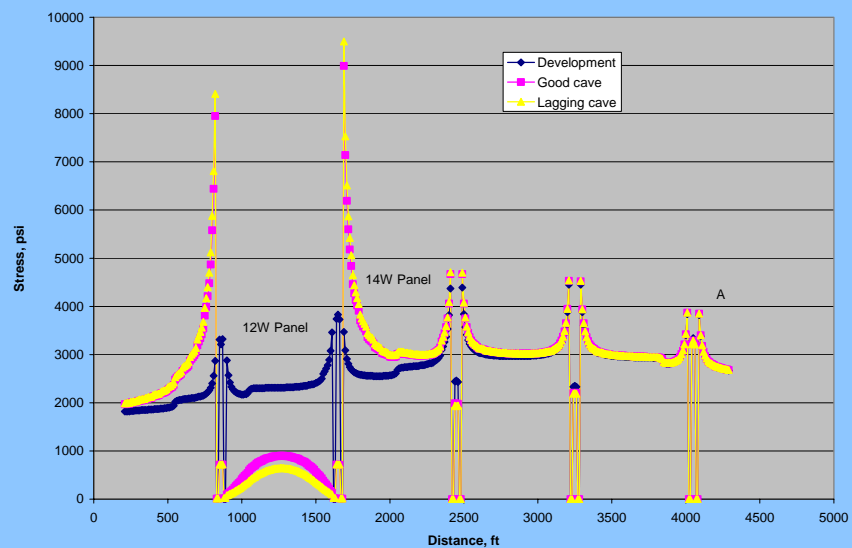




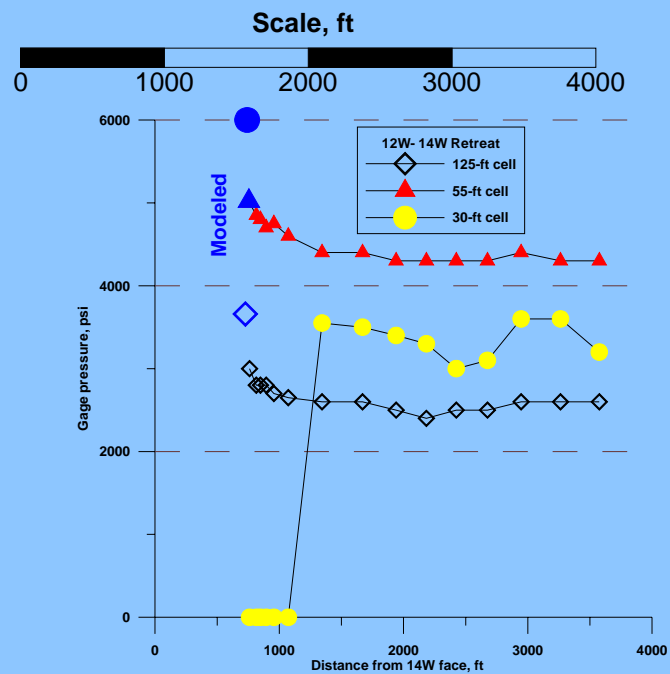
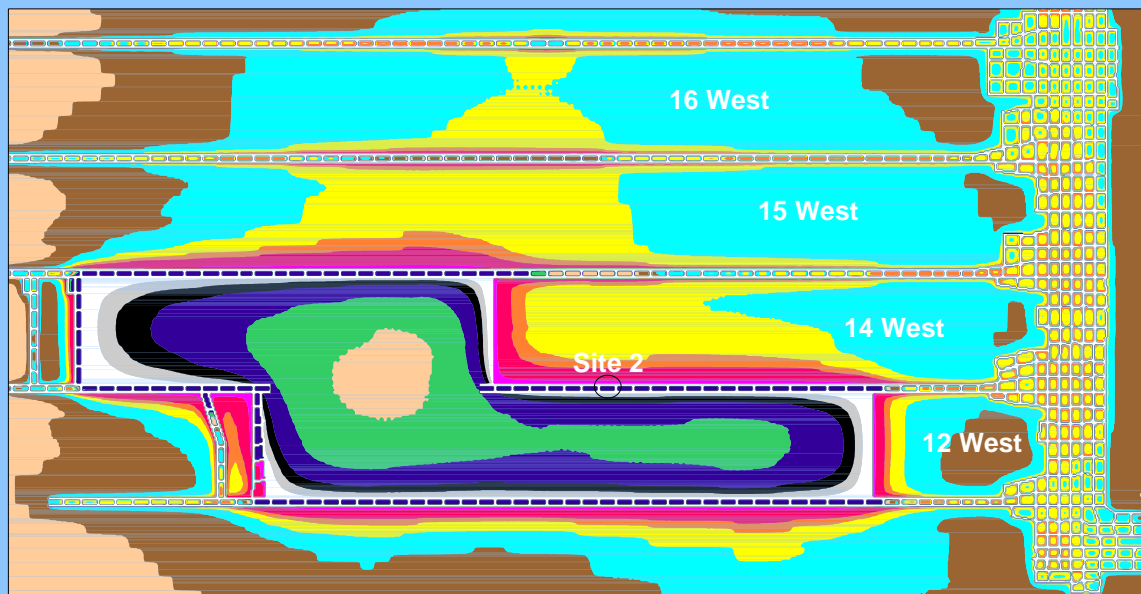
Stress, psi



Section A

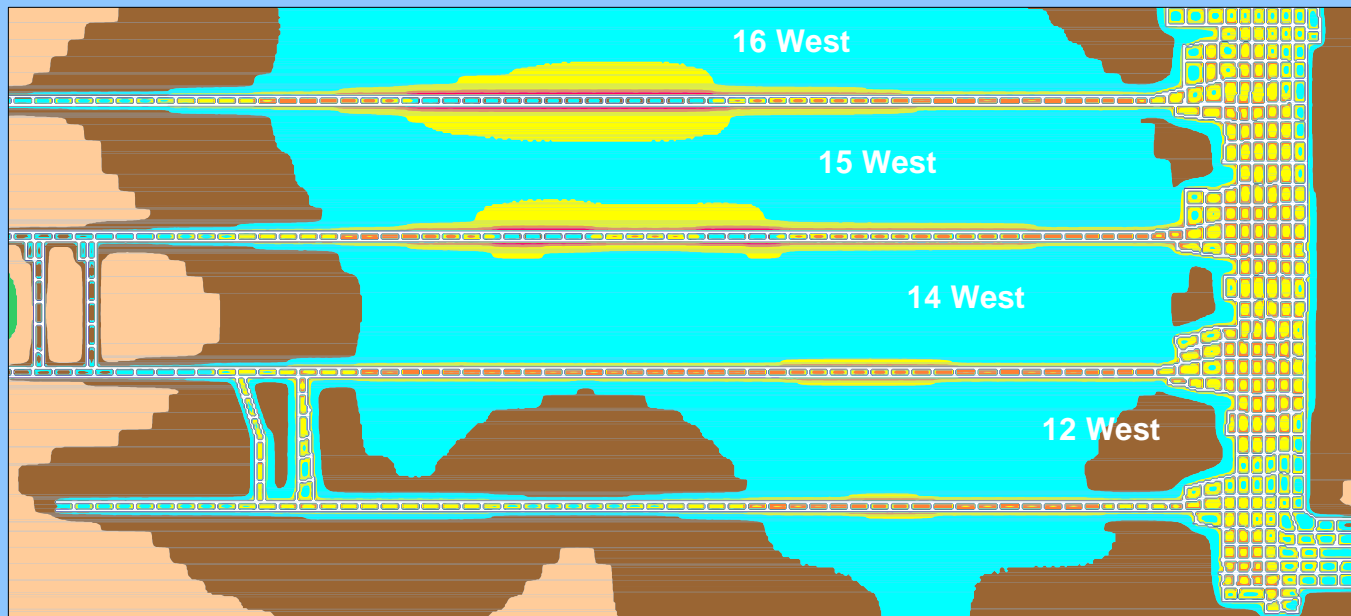


Vertical Stress Distribution on the Hiawatha Seam, Face 2-14W

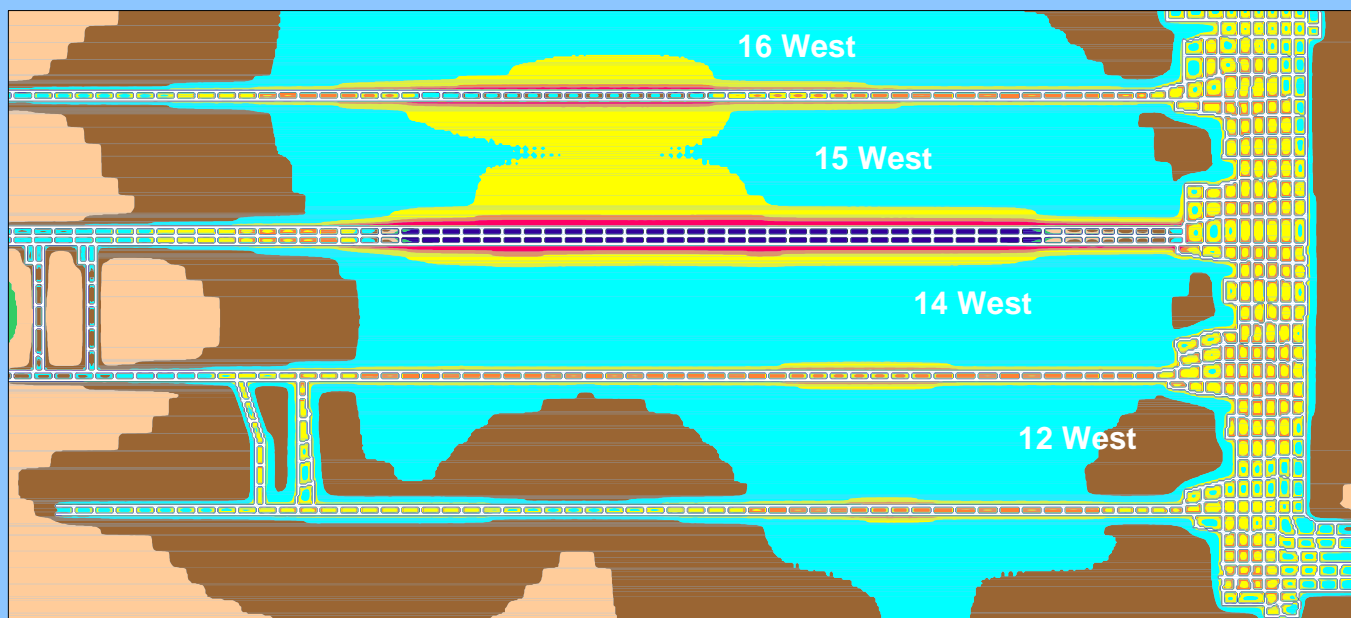
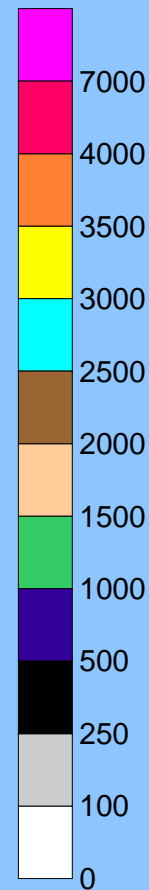


Compared 2-and 3-Entry, 14W HG

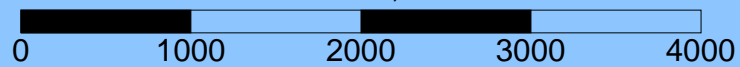
- Use the calibrated model
- Compare at three face positions
- Development
- Retreat 14W to location A, headgate loading
- Retreat 15W to location A, tailgate loading

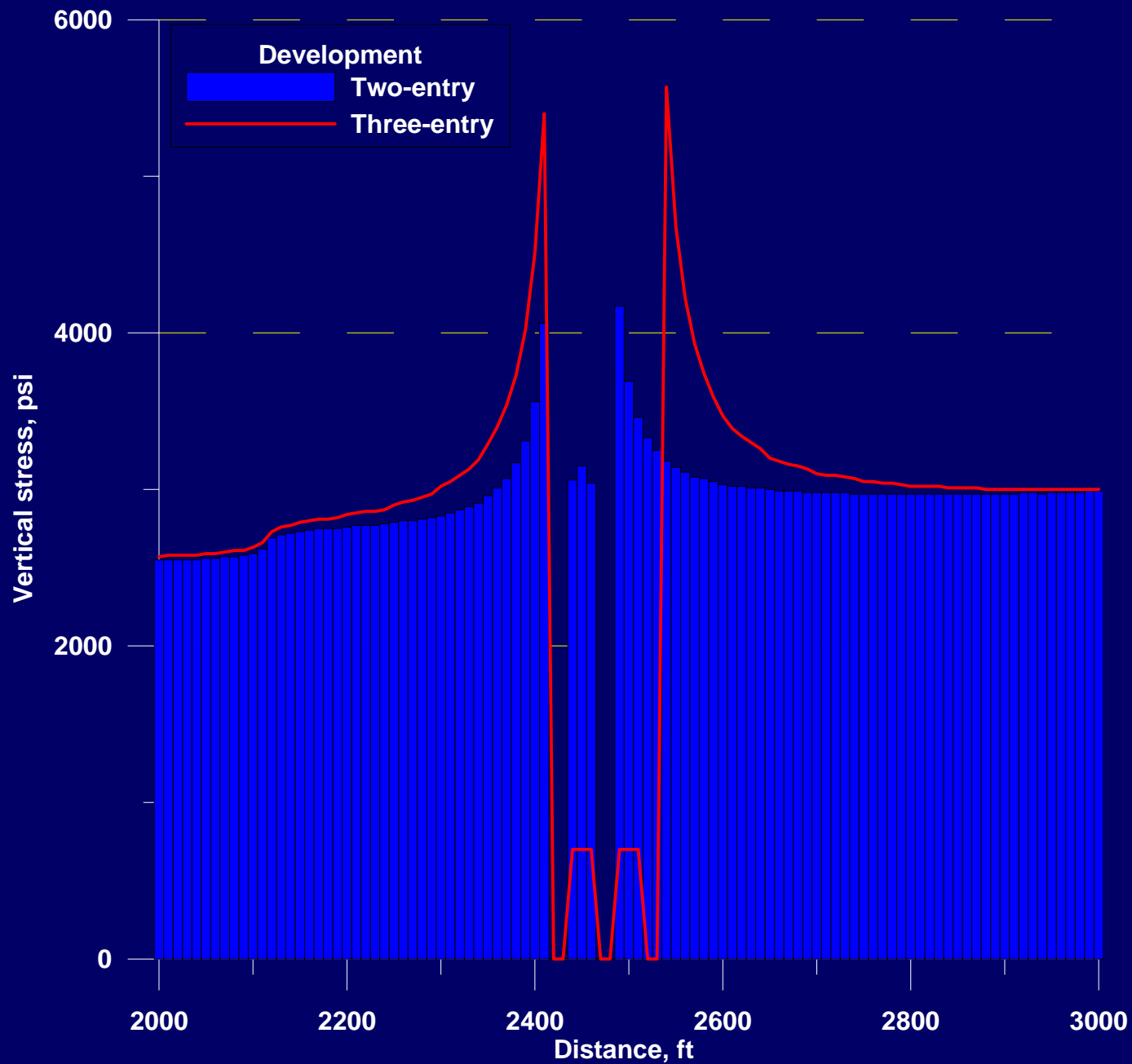


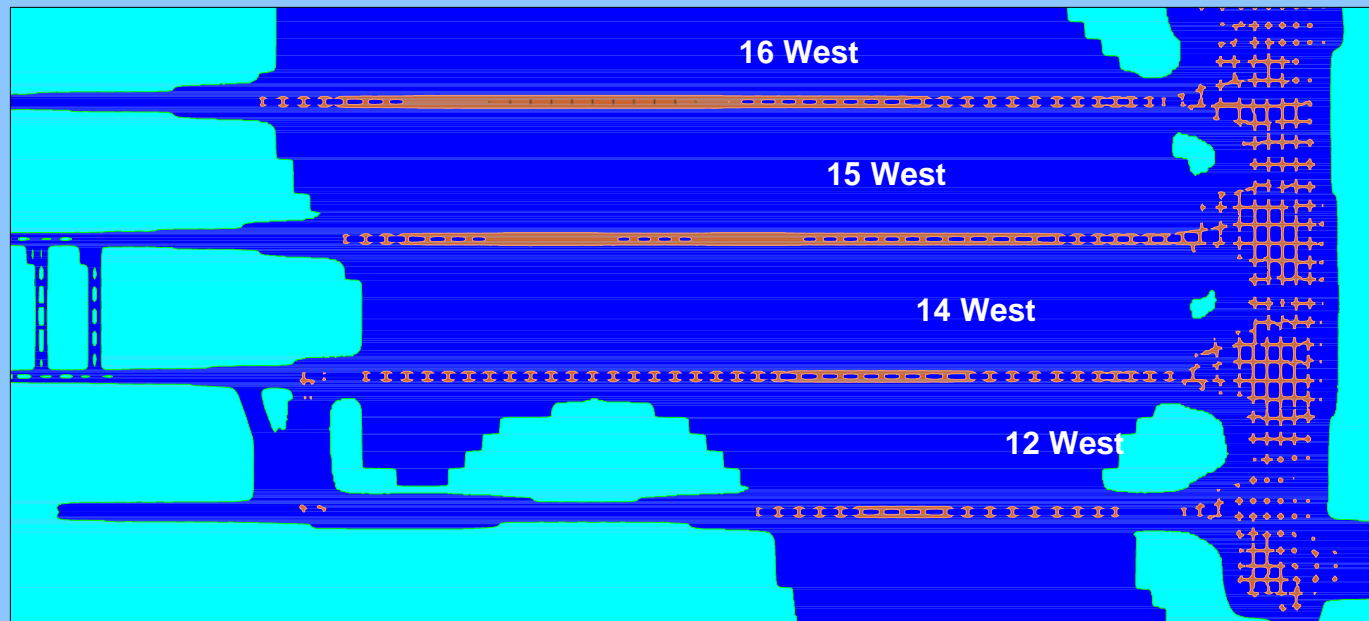
Stress, psi



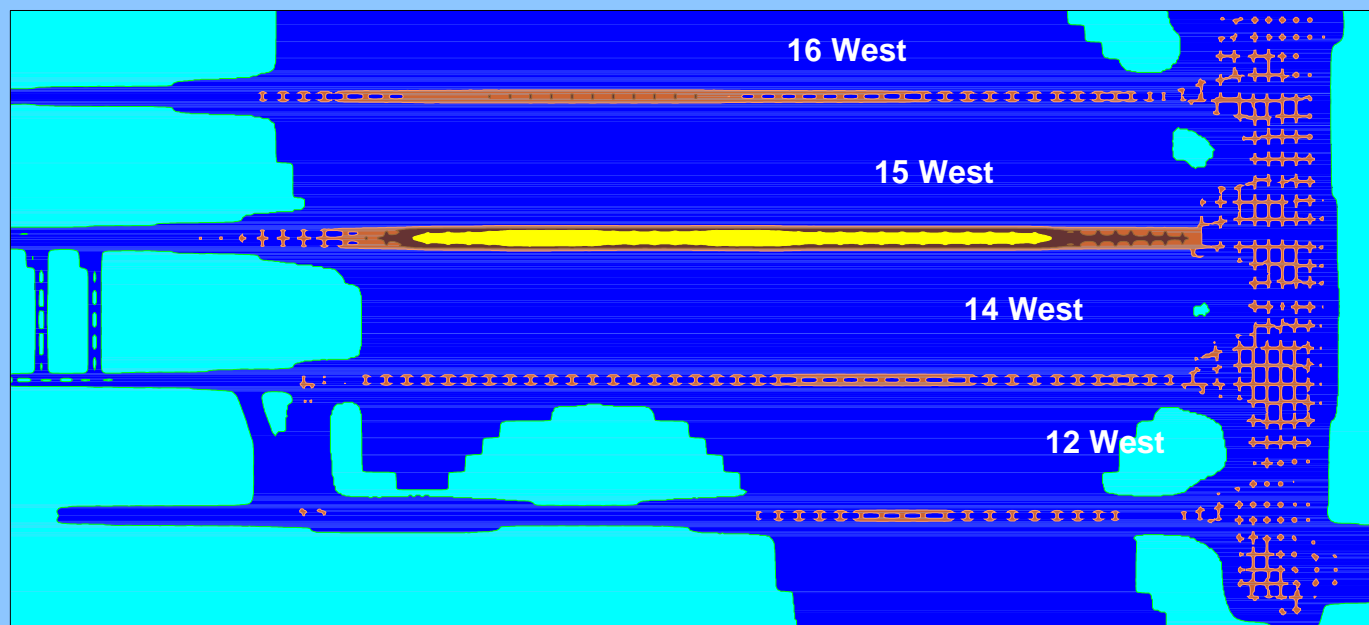
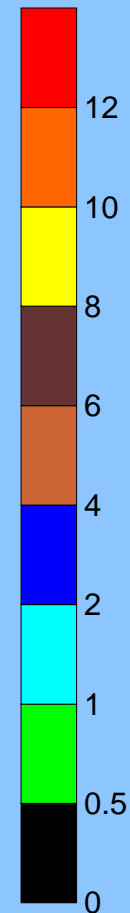
Scale, ft



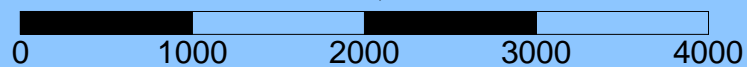


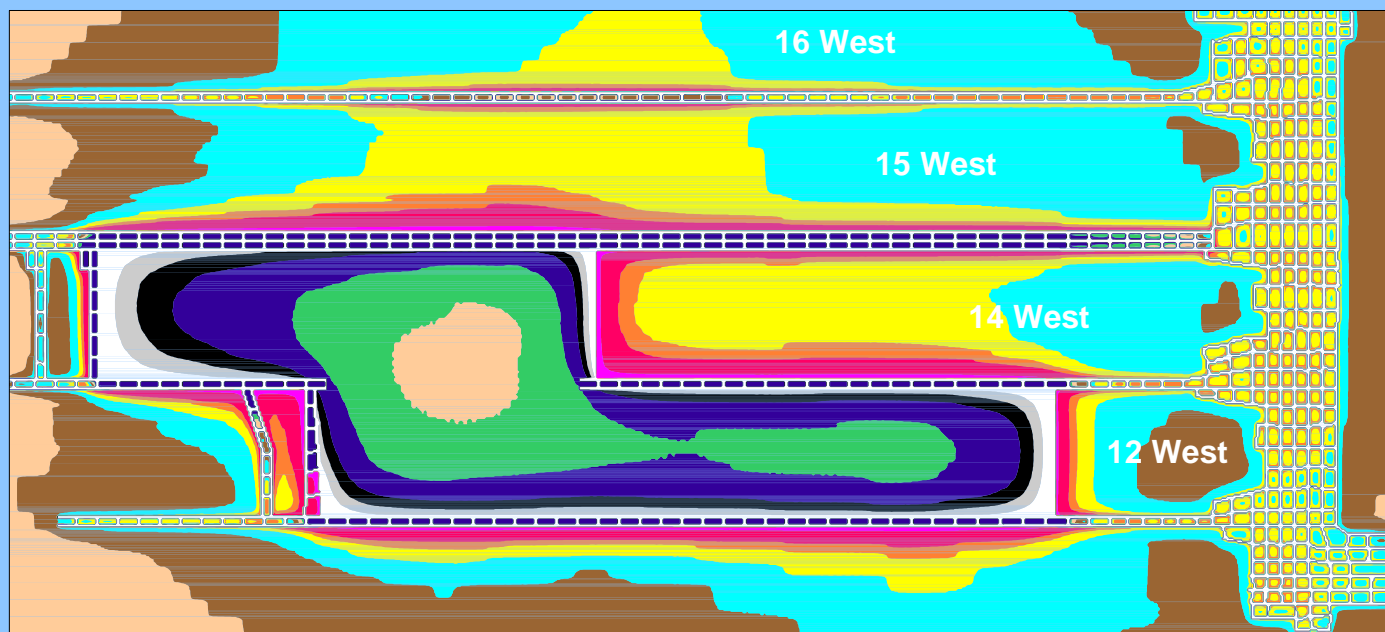
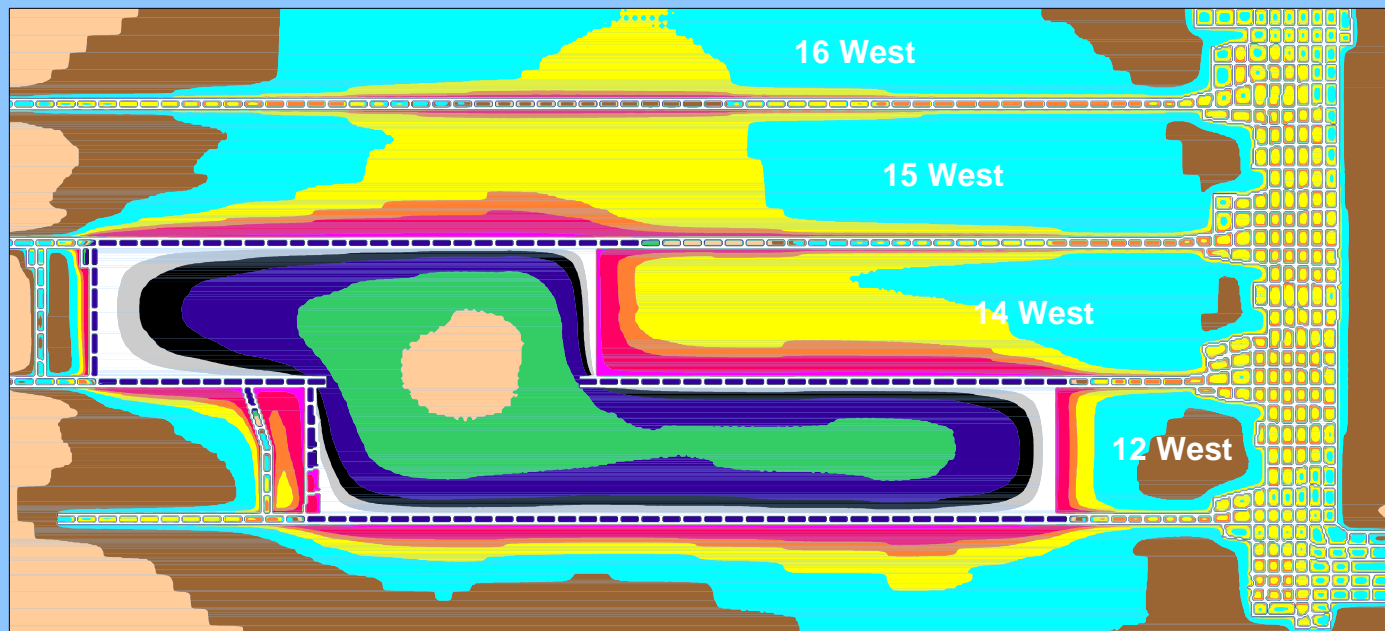


Convergence, in

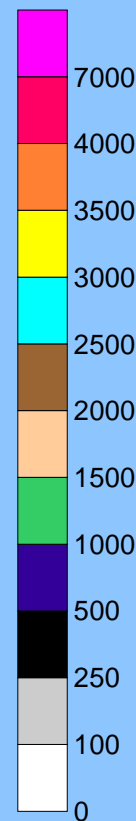


Scale, ft



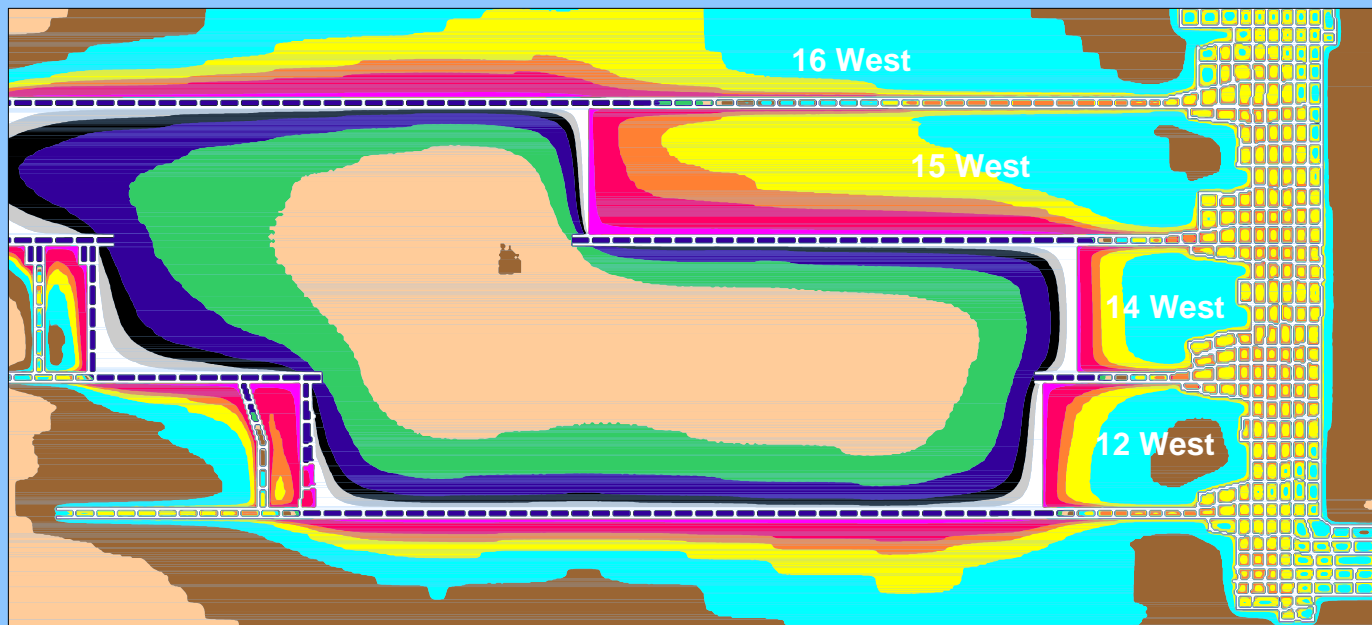


Stress, psi

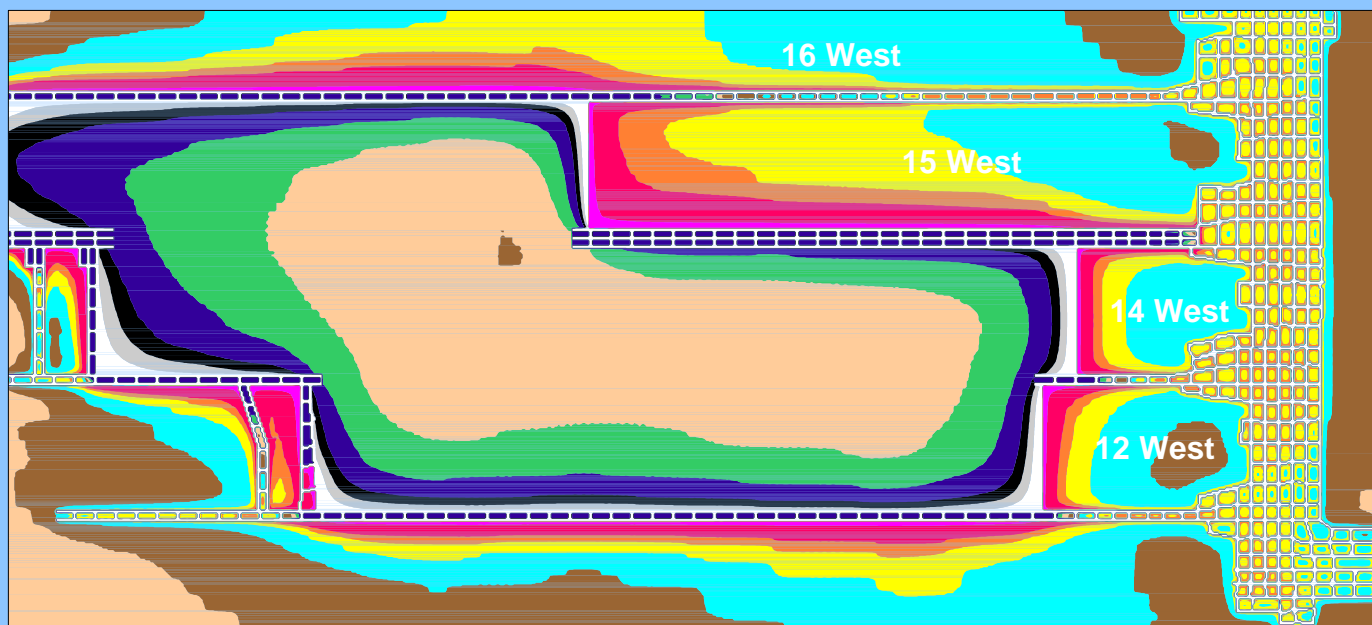
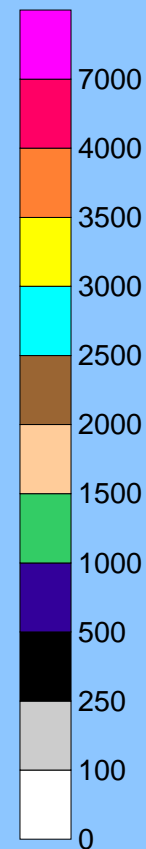


Scale, ft

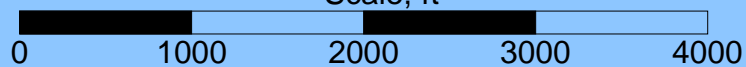


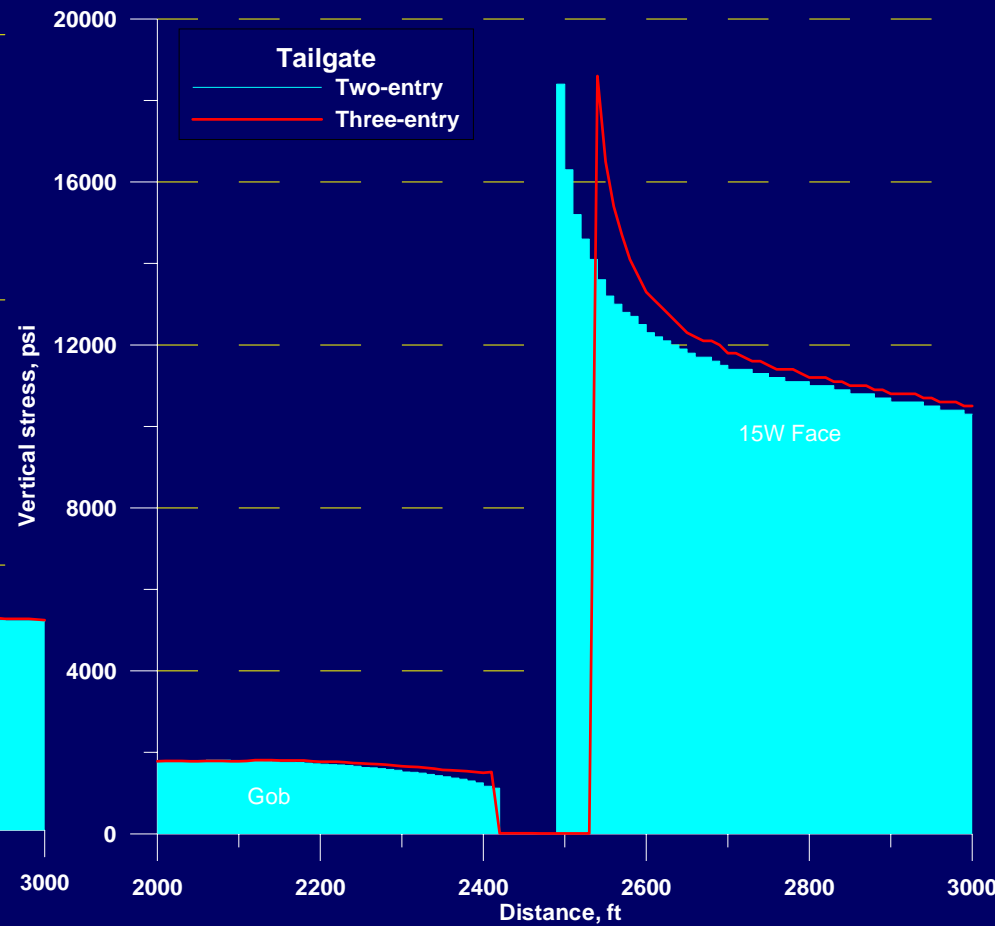
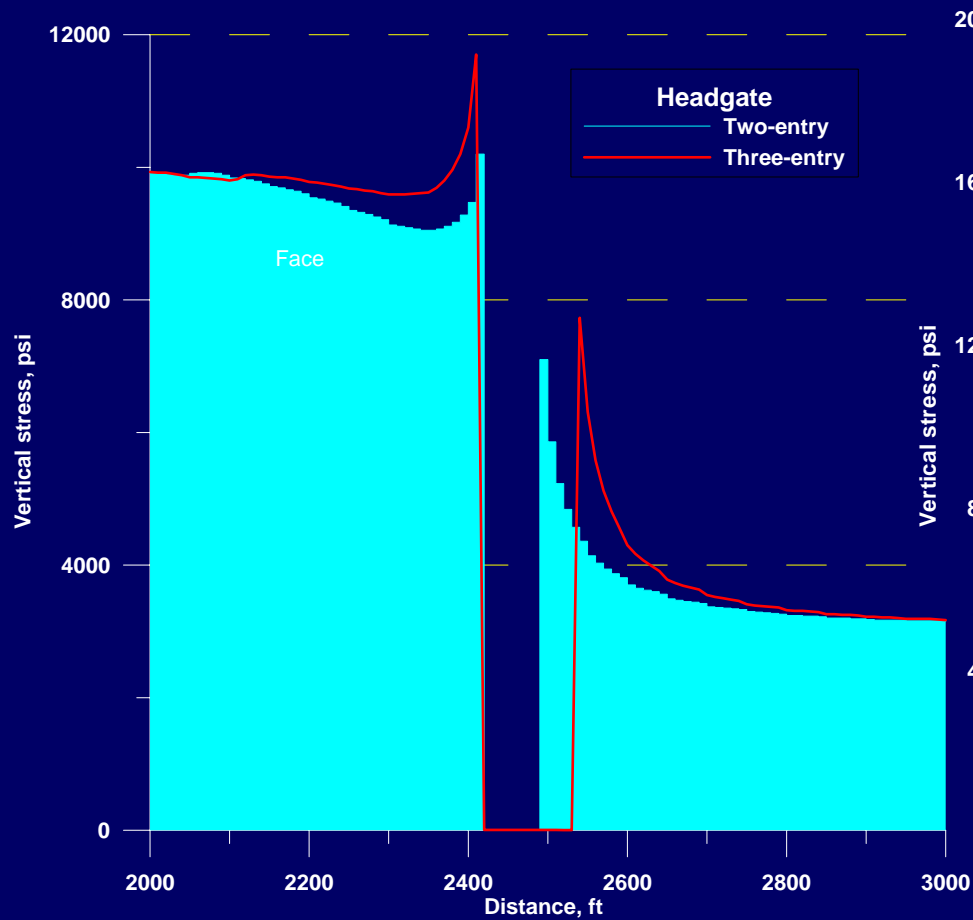


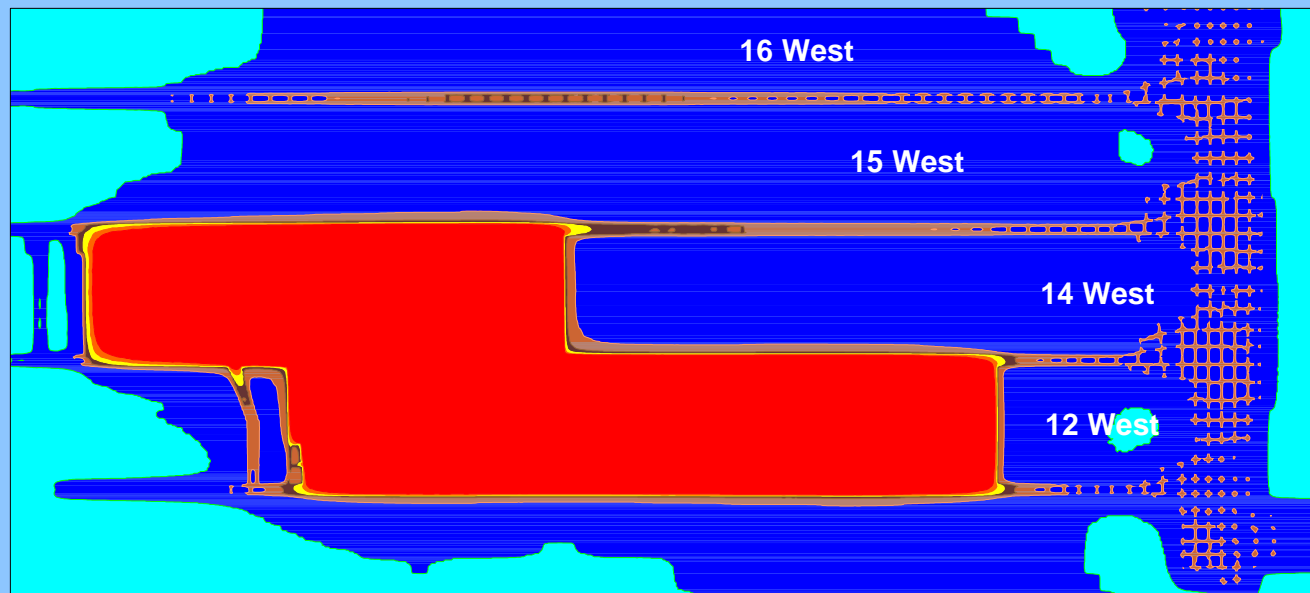
Stress, psi



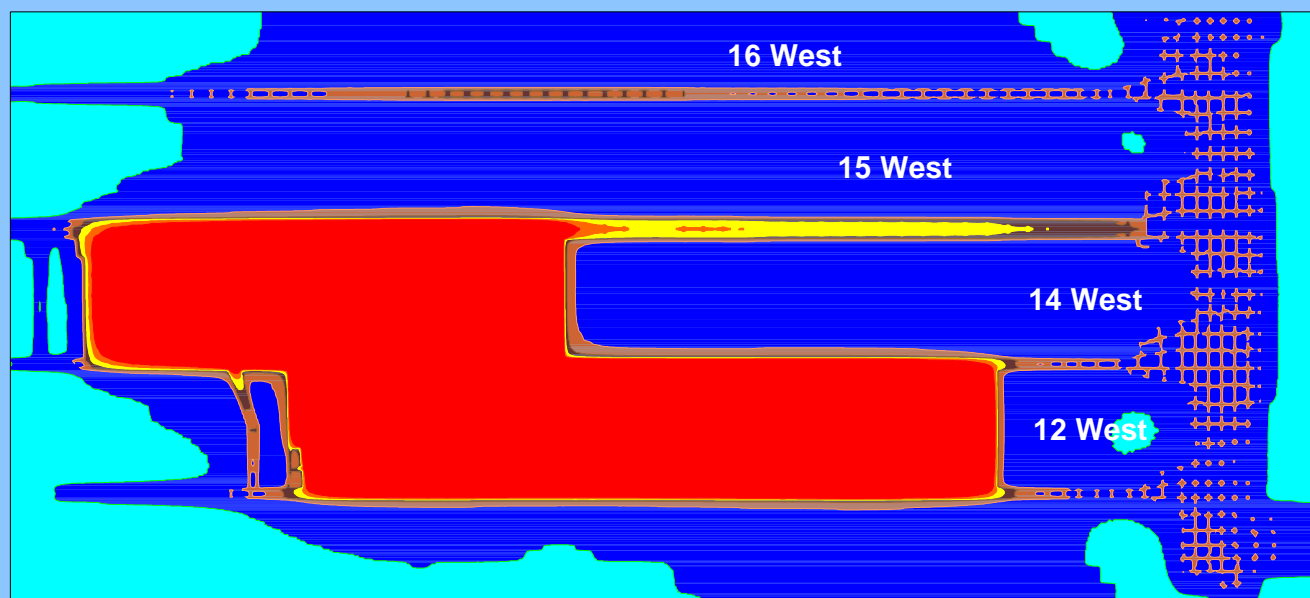
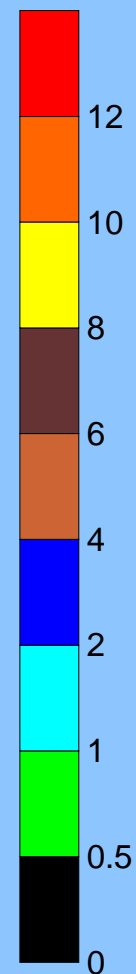
Scale, ft



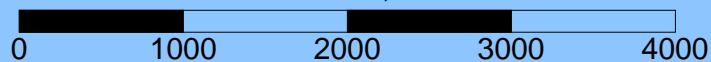


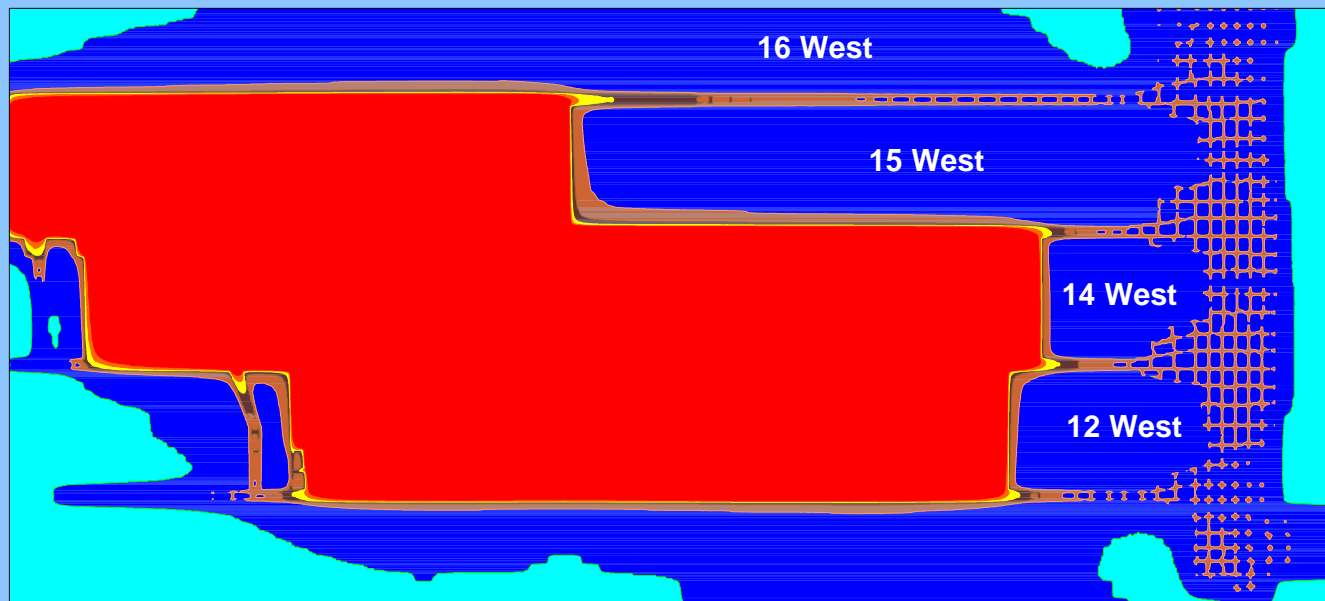


Convergence, in

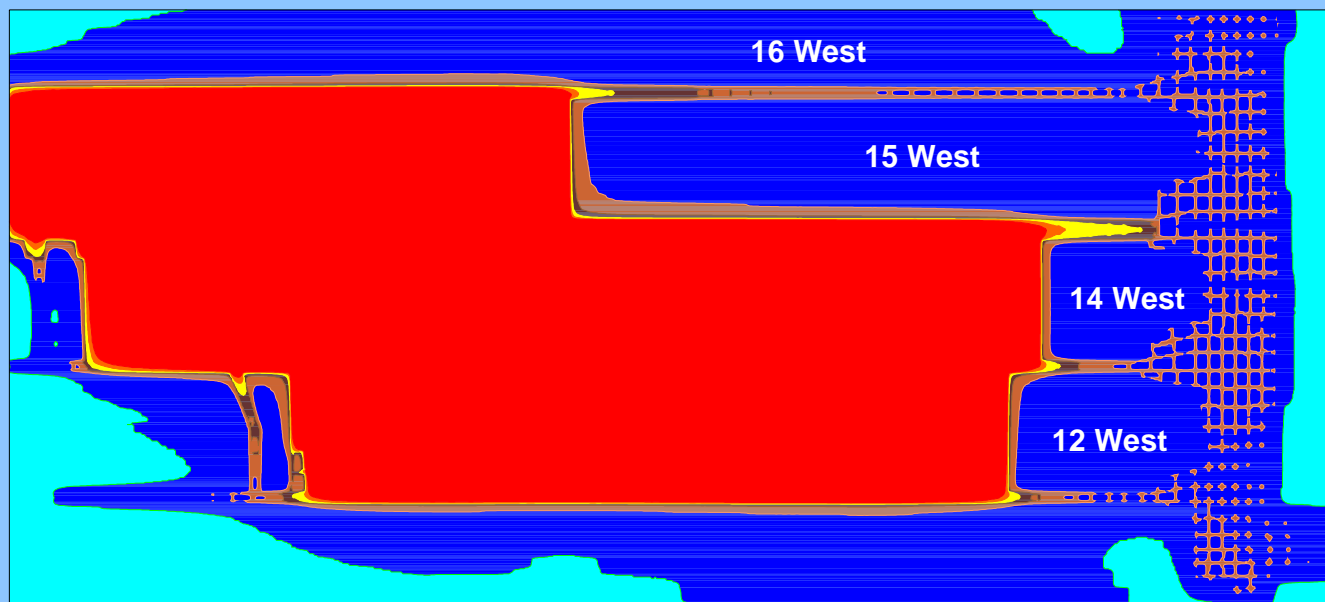
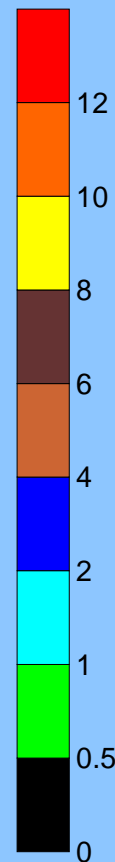


Scale, ft





Convergence, in



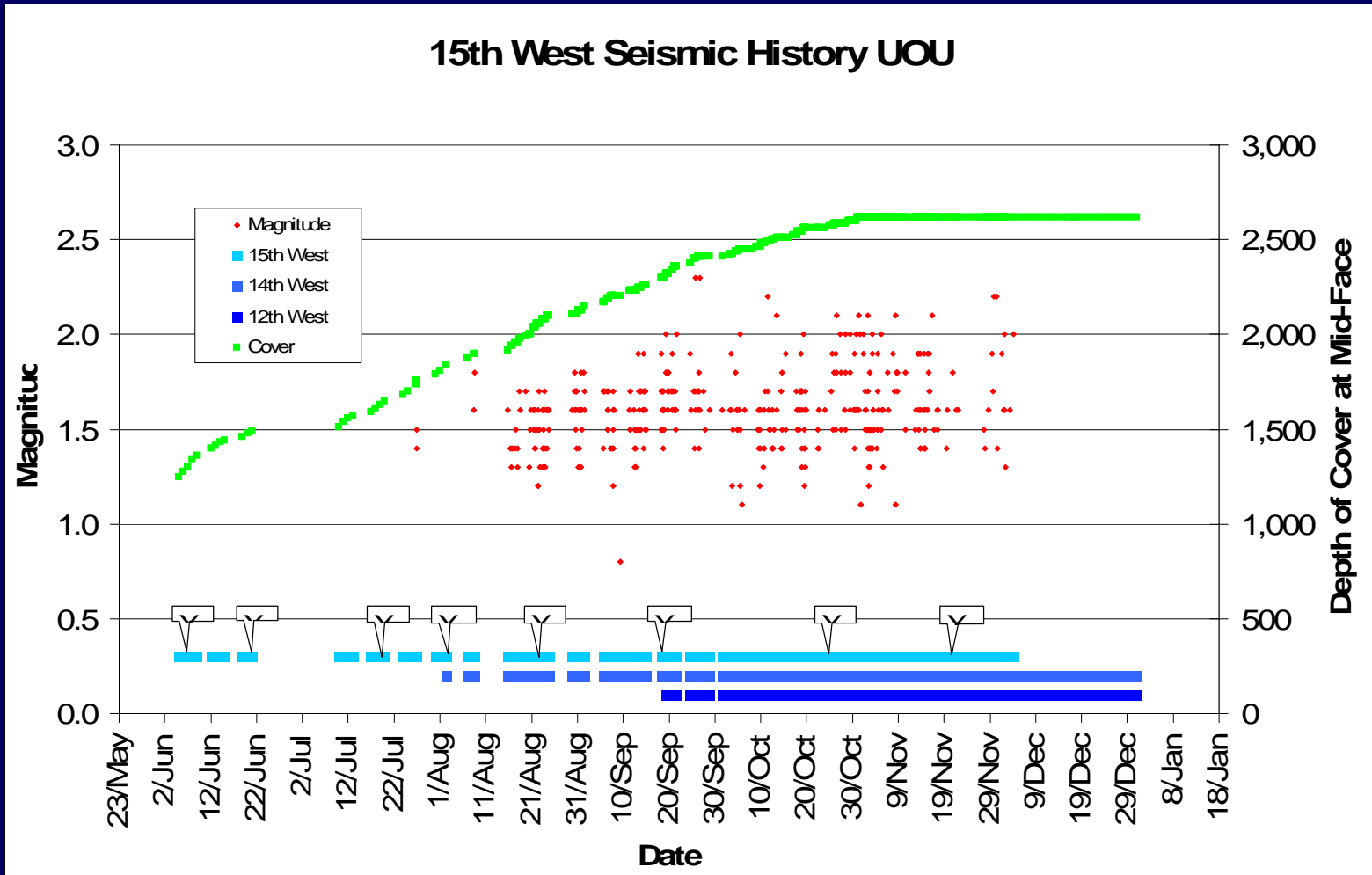
Scale, ft



Compared Roof-Floor Convergence, in

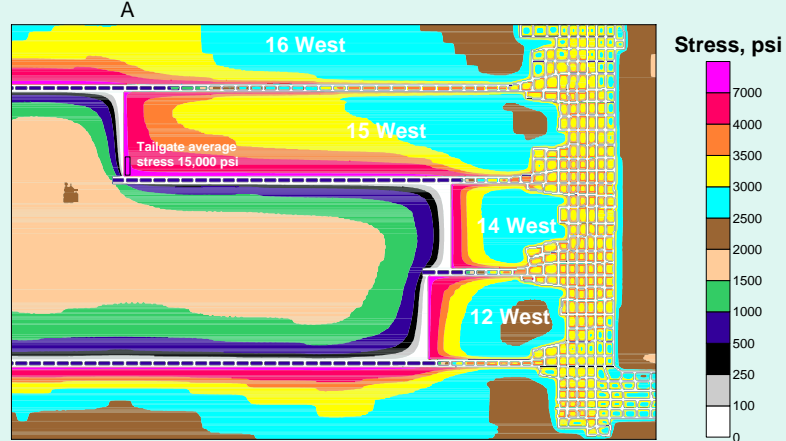
Mining Stage	Two-entry	Three-entry	% increase
Development	5.0-5.8	7.0-9.5	40-63
Headgate	8.8-11.9	9.7-15.0	10-26
Tailgate	21.3-23.6	21.5-23.9	1
* Compared to the middle-entry		29*	36*

Seismicity and Dynamic Loads



Conclusions

- From a geotechnical point-of-view, the two-entry system is better than the three-entry system; an assertion supported by the successful use of the 2-entry yielding gate system within the last 4 decades in many Utah operations
- Depending on site-specific conditions, one needs to make a decision on the necessity of the 2-entry system to ensure stability; decisive factors are geology, depth and cave conditions. The poorest cave conditions persist in the Book Cliff mines.
- Besides obvious benefits of reduced ground exposure, site-specific simulations at Mill Fork shows:
 - Significant reduction on convergence (both in length and duration)
 - And thus a two-entry system is judged to be better for EW deep, semi- lagging caving longwall conditions
- Certain geologic and stress conditions requires the use of barrier pillars located at strategic locations and/or between panels to moderate stress and ensure stability when using the 2-entry system.



Caving and Stress Level Model- Side-by-Side Extraction

